RESEARCH NEEDS ON THE WEED CONTROL PROBLEM

UNITED STATES DEPARTMENT OF AGRICULTURE
JANUARY 6, 1961

DEPARTMENT OF AGRICULTURE
WASHINGTON 25, D. C.

January 13, 1961

Hon. Richard B. Russell
Chairman, Subcommittee on
Agricultural Appropriations
United States Senate

Dear Senator Russell:

In Senate report No. 1404, page 3, on the 1961 Department of Agriculture and Farm Credit Administration Appropriation Bill, the Senate Committee on Appropriations included the following directive:

"The committee is impressed with the potential opportunity to reduce farm production costs through the improvement of weed control methods. Losses from weeds are one of the major costs of agricultural production. The control of weeds is the greatest single obstacle to mechanization of production in most crops.

"Because farmers can derive considerable savings from the development of improved weed control materials and practices for use in cotton and other field crops, horticultural crops, and pastures, the committee directs the Department to make a study to determine the need for such measures, including a regional laboratory or other facilities whereby basic weed control research could be speeded up, and to report to the committee not later than February 1, 1961."

There is submitted herewith the Department's report on the research needs related to this problem. The report sets forth the significant aspects of the weed control problem and its relation to agriculture in the United States, describes the type and extent of research in this area now being carried out by State and Federal research organizations, and identifies areas where further research effort could contribute to the solution of the many problems involved.

In developing the information a working group composed of research specialists from the Agricultural Research Service was appointed. The working group consulted Federal research agencies, and interested farm and industry groups and individuals. Information and suggestions obtained through these contacts were considered in developing the recommendations contained in the report. Names of groups and individuals contacted are listed in the report.

While the research needs on weed control are recognized, there are many important research needs in other areas that are of equal or greater urgency to the welfare of American agriculture and the Nation. The scope of research on weed control

currently underway in the Department, as well as additional research effort that might be made, must necessarily be considered in relation to overall research needs and available resources.

The location of the facilities that are recommended for the Northeastern Region has been tentatively identified as Beltsville, Maryland. However, the Department will need to give further consideration to this location in connection with subsequent determinations to be made in connection with the future development of the Agricultural Research Center at Beltsville.

The results of this study, along with similar studies in other research areas and other known research needs, will be given careful consideration in connection with the development of future budgets. The Department of Agriculture will continue to consider all research needs and attempt to provide, within available resources, for a balanced research program that will be of maximum value to American agriculture.

Sincerely yours,

E. T. Benson

Secretary

RESEARCH NEEDS

ON

THE WEED CONTROL PROBLEM

United States Department of Agriculture

January 6, 1961

CONTENTS

TABLES

THE WEED CONTROL PROBLEM

Weeds have plagued man in his agricultural pursuits since biblical times in spite of backbreaking efforts to control them by hand and mechanical methods. Today weeds still constitute one of the major items in the production costs of food, feed, and fiber crops. Weeds also present costly control problems in farm ditches and ponds, on numerous industrial sites, and other noncrop areas and they adversely affect the health of millions of our population by causing allergies and other ailments. Cost of controlling weeds and losses from failing to control them are borne directly or indirectly by all facets of private and public life.

Although much progress has been made in improving weed control methods, the weed problem still represents a major challenge to optimum efficiency in farming operations because of the continuing upward spiral of labor and other production costs which contributes to reduction in producer's net income. Moreover, the introduction of new and powerful chemical tools and the prospect of broader utilization of biological control agents open new horizons for productive research designed to solve our nation's weed problem. The challenges are not being met aggressively enough because scientific manpower and facilities to attack the problem are currently inadequate.

The annual national loss in agricultural production due to weeds and the cost of weed control, estimated as high as $3.8 billion, are among the most serious problems facing the agricultural economy. Comprehensive and adequate data are not available on the losses caused by weeds in various crop situations. Some limited data serve to indicate, however, the economic threat weeds pose in producing crops. For example, in Montana, Canada thistle infestations of 3-5, 20-25, and 40-45 shoots per 15 square feet reduced yield of hard red spring wheat 4, 9, and 15 bushels per acre, respectively. In Washington downy brome infestations in alfalfa reduced hay yield 1 ton per acre. Fifteen mustard plants per square foot reduced oat yields 11 bushels per acre in New York. Onion growers in Colorado currently spend about $60 per acre for hand weeding and in Wyoming the cost of weed control in sugar beets is about $23 per acre. Brush on grazing land in Louisiana reduced forage eaten by cattle by over 2-1/2 tons per acre. In Hawaii the sugarcane industry spends about $7 million per year to control weeds in the crop. In 17 western states the farm value of water lost through aquatic and bank weeds on 130,000 miles of irrigation canals and laterals and the cost of control measures totaled $13.8 million in 1957, according to a recent survey.[1/] The annual labor

1/ Timmons, F. L. 1960. "Weed control in western irrigation and drainage systems - losses caused by weeds, cost and benefits of weed control." ARS 34-14, September 1960. 22 pp. Illus. (A joint publication by the Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Reclamation, U. S. Department of the Interior.)

THE WEED CONTROL PROBLEM

Weeds have plagued man in his agricultural pursuits since biblical times in spite of backbreaking efforts to control them by hand and mechanical methods. Today weeds still constitute one of the major items in the production costs of food, feed, and fiber crops. Weeds also present costly control problems in farm ditches and ponds, in numerous industrial sites, and other noncrop areas and they adversely affect the health of millions of our population by causing allergies and other ailments. Cost of controlling weeds and losses from failure to control them are borne directly or indirectly by all facets of private and public life.

Although much progress has been made in improving weed control methods, the weed problem still represents a major challenge to optimum efficiency in farming operations because of the continuing upward spiral of labor and other production costs which contributes to reduction in producer's net income. Moreover, the introduction of new and powerful chemical tools and the prospect of broader utilization of biological control agents open new horizons for productive research designed to solve our nation's weed problem. The challenges are not being met aggressively enough because scientific manpower and facilities to attack the problem are currently inadequate.

The annual national loss in agricultural production due to weeds and the cost of weed control, estimated as high as $3.0 billion, are among the most serious problems facing the agricultural economy. Complete and adequate data are not available on the losses caused by weeds in various crop situations. Some limited data serve to indicate, however, the economic threat weeds pose in [illegible] crops. For example, in Montana, Canada thistle infestations of 3-5, 20-35, and 40-45 shoots per 15 square feet reduced yield of hard red spring wheat [illegible], 9, and 15 bushels per acre, respectively. In Washington downy brome infestations in alfalfa reduced hay yield 1 ton per acre. Fifteen mustard plants per square foot reduced oat yields 11 bushels per acre in New York. Onion growers in Colorado currently spend about $60 per acre for hand weeding and in Wyoming the cost of weed control in sugar beets is about $12 per acre. Broom [illegible] on [illegible] land in Louisiana reduced forage eaten by cattle by over 2-1/2 [illegible] The sugarcane industry spends about $7 million [illegible] in the crop. In 17 western states the farm [illegible] aquatic and bank weeds on 130,000 miles of [illegible] streams and the cost of [illegible] measures totaled [illegible] to a recent survey.[1] The annual labor

[1] [illegible] in western irrigation and drainage [illegible] cost and benefits of weed control." [illegible] joint publication by [illegible] U. S. Department of Agriculture, [illegible] Bureau of Reclamation, U. S. Department of the Interior.)

requirements for controlling weeds in cotton in Mississippi by handhoeing and conventional cultivation ranged from 20 to 41 man-hours per acre in 1954 to 1956. The need for a truly effective and economical method of controlling grasses and other weeds in cotton that would reduce hand-labor requirements and maintain the inherent quality of cotton during mechanical harvesting is probably the most important single technical problem that faces the cotton-producing industry today.

Allergies due to weeds such as ragweed and poison ivy are of concern to the whole population. Many poisonous weeds such as tall larkspur, halogeton, and others make livestock unthrifty and cause numerous deaths of domestic animals.

Diversity and Distribution of Weed Species

Different weeds occur in different regions of the United States in that rainfall, soils, and climatic conditions vary widely. Each region is characterized by different cropping practices which add complications to development of selective measures for the control of weeds. The chief problem encountered in the use of herbicides to control weeds selectively in crops involves presence or absence of fundamental physiological differences between the crop and the weeds to be controlled. Insects and plants are sufficiently different so that scientists have found a number of chemical compounds that may be used to kill insects without injury to the plants they infest. On the other hand, in developing selective chemical weed control measures, scientists must obtain differential reactions of weeds and crop plants that may be very similar physiologically. For example, wild oats and cultivated oats are similar botanically. Johnson-grass and sorghum are species of the same genus, and finding margins of selectivity between such species is difficult. Sufficient progress has been made, however, to indicate that such a degree of herbicidal selectivity can be achieved through intensive research. To develop such measures scientists must have a basic understanding of the weeds. Too little is known about the basic aspects of reproduction of our most common weeds. What factors control the germination, longevity, and viability of weed seeds? How do environmental factors such as light, temperature, and moisture affect weed reproduction? Future progress in development of efficient chemical and other weed control measures will be hampered if such fundamental information is not available.

Weeds cause damage in many ways, and the following classification indicates some of the most serious ones:

1. Losses in productivity and in efficiency of land use

   The yields of crops and livestock are reduced or impaired by failure to control weeds. In many instances the presence of particular weeds in fields determines the choice of crops to be planted. Weeds tend to reduce the value of agricultural land. They increase production

and harvesting costs, impede production mechanization, and reduce efficiency of equipment and other operations. Excessive tillage to control weeds frequently causes damages to the crops and soil. Aside from the loss in production of forage, brush on rangelands increases the cost of handling livestock and prevents efficient management.

2. Losses in product quality

Weeds occurring in crop products such as the lint of cotton, and hay and in leafy and other vegetable crops reduce their quality. In addition, weeds such as wild onion, wild garlic, and bitter weed impart off-flavors to milk and frequently the inferior product cannot be sold. The occurrence of burs in wool is one of the greatest losses suffered by the wool industry. Noxious weed seed contamination greatly reduces crop seed value and sometimes prevents its sale. Weeds and weed debris in grains and other farm products reduce their sales value or cause spoilage in storage. Certain serious contaminants, such as crotalaria seed in corn or soybeans, necessitate costly cleaning operations prior to marketing.

3. Reduction in efficiency of water management

Aquatic weeds reduce markedly the flow of water in irrigation and drainage canals. Reduced flow causes high water levels in canals and streams that result in (a) flooding, (b) seepage into adjoining areas or poor drainage, (c) breaks in canal banks, and (d) inadequate delivery of irrigation water to farms located at a distance from the water source. In addition reduced velocity of flow causes increased siltation, reduced carrying capacity, and necessitates more frequent dredging. Aquatic weeds that break loose and weeds of the floating type obstruct weirs, gates, and other structures. Also algae and omit fragments of plant material clog sprinkler irrigation system equipment. Aquatic weeds promote breeding grounds for obnoxious insects such as mosquitos. They reduce recreational values by interfering with fishing, swimming, boating, hunting, and navigation of otherwise navigable streams. The decaying organic matter produced by aquatic weeds causes off-flavors in potable waters. Weeds on watershed areas omit utilize appreciable amounts of water and thereby deny its use for the production of food, feed, and fiber.

4. Losses in human efficiency

Weeds such as poison ivy and ragweed that cause hayfever and other debilitating allergies contribute markedly to human misery and make necessary the annual expenditure of large sums for medical attention and for travel to noninfested areas during the hayfever seasons. In addition, many hours of manpower are lost.

5. Losses due to harboring of insects and disease-producing organisms

Propagation and survival of many harmful insects are favored by the presence of weeds on which they can breed and feed. For example, Russian thistle serves as an important food plant for migrating beet leafhoppers that transmit curly top virus to sugar beets and vegetables. Weeds also serve as alternate hosts for many plant diseases such as wheat rust which cause tremendous losses to agriculture each year.

6. Weeds and brush on public and private noncrop areas

Weeds on ditchbanks, on highway, railroad, and utility rights-of-way, in fence rows, and on other areas adjacent to cropland produce large quantities of seed and thus serve as reservoirs for invasion of fields through movement of seed by wind, water, man, and animals or by vegetative spread. Weeds in the above areas, as well as in lawns, parks, golf courses, playgrounds, cemeteries, and other public and privately owned areas are unsightly and increase maintenance costs. Trees and other vegetation that obstruct and damage telephone and power transmission lines are a particular problem and weeds and brush on highway rights-of-way obstruct visibility and increase traffic hazards.

Other Specific Problems

Usage of herbicides to control weeds more than doubled in the decade between 1949 and 1959. In 1959 an estimated 86 million pounds of organic herbicides and 92 million pounds of inorganic herbicides were used in the United States. These materials cost users an estimated $73 million. Benefits accruing from use of herbicides to control weeds are indicated by the following examples. The control of big sagebrush with herbicides costing $2.25 to $3.25 per acre gave an annual net gain of forage with an estimated value of $1.68 an acre in Oregon. The experimental control of barnyard grass in rice by proper use of CIPC resulted in an average yield increase valued at $67 per acre in Arkansas from 1955 to 1957. Use of herbicides for weed control in cotton between 1954 and 1956 reduced labor requirements by 16 to 35 man-hours per acre in Mississippi, and control of winter weeds in spinach in the same State resulted in benefits valued at $162 per acre.

Although 50 million acres of cropland were sprayed with herbicides for weed control in 1959, weeds still cost farmers some 10 to 15 percent of the potential productivity of all crop and grazing lands. Weeds occur in extensive agricultural lands of low economic potential where methods other than chemical and cultural techniques are needed for weed control. In addition, the cost of weeds to non-agricultural enterprises has been estimated to be as much as $1 billion annually. Accordingly, improved chemicals, cultural techniques, biological control agents, and other methods are still critically needed.

Propagation and survival of many harmful insects are favored by the presence of weeds on which they can breed and feed. For example, Russian thistle serves as an important food plant for [illegible] beet leafhoppers that transmit curly top virus to sugar beets and vegetables. Weeds also serve as alternate hosts for many plant diseases such as wheat rust which cause tremendous losses to agriculture each year.

Weeds on ditchbanks, on highway, railroad, and utility rights-of-way, in fence rows, and on other areas adjacent to cropland produce large quantities of seed and thus serve as reservoirs for invasion of fields through movement of seed by wind, water, man, and animals or by vegetative spread. Weeds in the above areas, as well as in lawns, parks, golf courses, playgrounds, cemeteries, and other public and privately owned areas are unsightly and increase maintenance costs. Trees and other vegetation that obstruct and damage telephone and power transmission lines are a particular problem and weeds and brush on highway rights-of-way obstruct visibility and increase traffic hazards.

Other Specific Problems

Usage of herbicides to control weeds more than doubled in the decade between 1949 and 1959. In 1959 an estimated 86 million pounds of organic herbicides and 92 million pounds of inorganic herbicides were used in the United States. These materials cost users an estimated $7[illegible] million. Benefits accruing from use of herbicides to control weeds are indicated by the following examples. The control of big sagebrush with herbicides costing $2.25 to $3.25 per acre gave an annual net gain of forage with an estimated value of $1.68 an acre in Oregon. The experimental control of barnyard grass in rice by proper use of CIPC resulted in an average yield increase valued at $67 per acre in Arkansas from 1955 to 1957. Use of herbicides for weed control in cotton between 1954 and 1956 reduced labor requirements by 16 to 35 man-hours per acre in Mississippi, and control of [illegible] weeds in spinach in the same State resulted in benefits valued at $162 per acre.

Although 50 million acres of cropland were sprayed with herbicides for weed control in 1959, weeds still cost farmers some 10 to 15 percent of the potential productivity of all crop and grazing lands. Weeds occur in [illegible] as [illegible] agricul[illegible]ural lands of low economic potential where methods other [illegible] chemical and cultural techniques are needed for weed control. In [illegible]ition, [illegible]s of weeds to non-agricultural enterprises are been [illegible]mated to be as much as $1 bil[illegible] annually. Accordingly, improved [illegible], [illegible]tural techniques, biological control agents, and other methods [illegible] l[illegible] [illegible]tically needed.

Because of desperate need for economical and labor-saving weed control measures, farmers are using new long-persisting herbicides on large acreages and information on the possible long-term effects of the chemicals on existing perennial crops, succeeding crops, and soils is largely non-existent. Most herbicides have not been thoroughly investigated as to selectivity, persistence, and mechanism of action and their occurrence as residues in plant tissues and in soils in various environments. The increasingly rapid introduction of new herbicides for use in controlling weeds in food and feed crops adds complexity to an already serious problem of pesticide residues in and on food, feed, and animal products. The nature and amount of herbicide residues in food crops grown on small acreages are of particular concern because potential sales of herbicides for these crops are too small to warrant development by the chemical industry. Some other herbicides in wide usage on feed and forage crops are inadequately tested with respect to possible residues in milk. Thus, farmers may be denied use of promising labor- and money-saving herbicides because of lack of basic information on the fate of the compound on or in the treated plants.

Educational Aspects and Program Coordination

The continuing expansion in the introduction and use of herbicides to replace or supplement present control measures has created needs for supplying farmers with new technological information to insure safe and efficient use of available herbicides and equipment for local farm situations. Research information obtained in weed control research programs must be published and properly disseminated to farmers on a continuing basis. Weed control will be expedited by training and providing additional weed control specialists to work with county agents, farmers, and others interested in weed control. The estimation of needs for such specialists is beyond the scope of this report.

The rapid progress being made in using synthetic organic chemicals for weed control has created a need for and an interest in both basic and applied research to exploit the full potential of using chemical energy instead of human and other forms to control weeds. The work conducted by various private and public agencies should be correlated on a continuing basis so as to insure maximum research efficiency.

Deficiency in Basic Research Information

Applied research to solve immediate economic weed control problems made great progress in reducing crop production costs over the past decade. With the manpower available, however, it has been impossible to investigate adequately the rapidly accumulating basic problems generated by the applied studies.

Because of [illegible] economical and labor-saving weed control measures, [illegible] mark [illegible] new long-persisting herbicides on large acreages and information on the possible long-term effects of the chemicals on existing perennial crops, succeeding crops, and soils is [illegible] non-existent. Most herbicides have not been thoroughly investigated as to selectivity, persistence, and mechanism of action and their occurrence as residues in plant tissues and in soils in various environments. The increasingly rapid introduction of new herbicides for use in controlling weeds in food and feed crops adds complexity to an already serious problem of pesticide residues in and on food, feed, and animal products. The nature and amount of herbicide residues in food crops grown on small acreages are of particular concern because potential sales of herbicides for these crops are too small to warrant development by the chemical industry. Some other herbicides in wide usage on feed and [illegible] crops are inadequately tested with respect to possible residues in milk. Thus, farmers may be denied use of promising labor- and energy-saving herbicides because of lack of basic information on the fate of the compound on or in the treated plants.

[illegible]

The continuing expansion in the introduction and use of herbicides to replace or supplement present [illegible] measures has created needs for supplying farmers with new technological information to insure safe and efficient use of available herbicides and equipment for local farm situations. Research information obtained in weed control research programs must be published and properly disseminated to farmers on a continuing basis. Weed control will be expedited by assigning and providing additional weed control specialists to work with county agents, farmers, and others interested in weed control. The estimation of needs for such specialists is beyond the scope of this report.

The rapid progress being made in using synthetic organic chemicals for weed control has created a need for and an interest in both basic and applied research to exploit the full potential of using chemical energy instead of human and other forms to control weeds. The work conducted by various private and public agencies should be correlated on a continuing basis so as to insure maximum research efficiency.

[illegible]

[illegible] immediate economic weed control problems made [illegible] crop production costs over the past decade, [illegible] yield. However, it has been impossible to investi- [illegible]

Weed control research presently involves a combination of basic and applied studies on the most critical of the weed problems. The accomplishments, though individually great, are collectively limited. There is a critical need for the development of principles of weed control which cut across many research areas including physiological, chemical, and biochemical studies on the nature, behavior and effects of herbicides and their degradation products in and on plants, animals and soils and in waters; botanical and ecological studies on weed characteristics; and engineering studies on principles and mechanics of herbicide application. Such basic research would be applicable to weed control in many different crops and situations.

RESEARCH UNDERWAY

The present research on weeds and their control is being conducted by scientists in widely scattered localities, and a considerable number of these scientists devote only a part of their time to such work. The aggregate of all research on these problems, by Federal and State employees, was estimated to be 269 professional man-years in 1960. Most of the research is devoted to the practical aspects of herbicide application in order that the most critical weed control problems may be met. Because the problems were so numerous and the workers so scattered, State and Federal weed workers initiated a voluntary exchange of condensed reports on the nature and magnitude of their activites. Tabulation of estimated State and Federal manpower by lines of research, presented in Table 1, is largely adapted from this information.

Table 1.

APPROXIMATE FEDERAL AND STATE PROFESSIONAL MAN-YEARS PRESENTLY DEVOTED TO WEED CONTROL RESEARCH

Lines of Work	Man-Years Federal	State	Total
I BASIC WEED CONTROL RESEARCH THAT APPLIES TO MOST CROPS AND SITUATIONS			
A. Evaluation of chemicals and biological agents for weed control			
1. Develop evaluation techniques and equipment	0.6	4.0	4.6
Involves widely scattered work on the development of laboratory, greenhouse, and field experimental methods and equipment for evaluation of new chemicals as herbicides.			
2. Determine activity and selectivity of agents	0.2	0.9	1.1
Involves limited cooperative studies with the chemical industry on the evaluation of the selective herbicidal properties of new chemicals to show the relations between chemical structure, herbicidal activity, and weed-crop selectivity.			
3. Search for new and more effective agents			
a. Preliminary	5.9	2.0	7.9
Involves cooperative research between the chemical industry and various public agencies in evaluating new chemicals for their inherent herbicidal properties and differential action on a wide range of crop and weed species, and the search in foreign countries for insects capable of selectively attacking weeds in rangelands.			

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
b. Secondary	6.0	10.4	16.4
Involves the evaluation of new chemicals shown to have promising weed control properties so as to determine individual crop tolerances and effectiveness in controlling important weeds in specific crops and situations when applied at different times and dosages by different techniques.			
	(12.7)	(17.3)	(30.0)
B. Nature, behavior, and effects of herbicides and their degradation products			
1. In and on plants and plant products	11.8	16.6	28.4
Involves investigations on the influence of environment, plant characteristics, and herbicidal formulation constituents on the absorption, penetration, and translocation of herbicides in weeds and crop plants including limited work on the mechanisms of herbicidal actions; influence of climate, plant morphology, and soil characteristics on the performance of herbicides in selectively controlling weeds and on their persistence in plants; degradation of a few herbicides in and on plant tissues; and effects of herbicides on the composition and quality of a few selected plants.			
2. In and on soils in relation to weed control and crop production			
a. Movement and persistence of herbicides	2.0	4.7	6.7
Involves investigations on the movement and persistence of herbicides in relation to the growth and development of crop plants and weeds including the influence of herbicide placement, climate, cultural practices, soil composition, and herbicide formulation on the performance of soil-applied herbicides.			

Lines of Work	Man-Years Federal	State	Total
b. Interactions of herbicides with soils	9.2	1.0	10.2
Involves studies on the effects of herbicides on rate of water intake and evaporation from soil under dryland farming; on soil erosion and structure; and on soil surface litter and organic matter. Lateral movement of herbicides in soils as influenced by simulated rainfall and soil slope. Phenomena involved in absorption and other interactions of herbicides with clay complexes.			
c. Ultimate fate of herbicides	0.5	-	0.5
Involves limited work on a few herbicides to determine herbicide disappearance or persistence as a part of an effort to catalog amount of herbicides degradated by various pathways following application for weed control.			
d. Determine the form and amount of herbicide residues	0.8	1.7	2.5
Involves largely cooperative research with the chemical industry to determine the nature of herbicide residues in soils and studies on levels of herbicidal activity detectable in soils following practical applications.			
3. In irrigation, drainage and other waters	0.2	1.5	1.7
Involves limited studies on the rate of disappearance of aquatic herbicides including the biological effects of treated irrigation water on crop plants.			

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
4. In and on animals and animal products	2.0	-	2.0
Involves limited studies on the toxicology of a few selected herbicides on animals and the effects of poisonous weeds on ruminants.			
	(26.5)	(25.5)	(52.0)
C. Principles of mechanics of herbicide application and weed seed removal	1.0	1.0	2.0
Involves largely studies on the development of techniques and equipment for separating weed seeds from forage legume and grass seed.			
	(1.0)	(1.0)	(2.0)
D. Weed characteristics and control in relation to desired plants and the feasibility of control practices under different conditions			
1. Life cycles and growth habits of weeds under different environments, including their susceptibility to control agents at different stages of growth and the germination and longevity of weed seeds.	2.8	2.6	5.4
Involves studies on the reproduction cycle of specific weeds such as halogeton, Canada thistle, quackgrass, nutsedge (nutgrass), and pond weeds, including the effects of climate, soils, competitive vegetation, and other factors on the spread of weeds and on longevity and germination of weed seeds; the response of specific weeds to selected herbicides and other weed control measures at different stages of growth.			
2. Relations between weeds and the biological control organisms that attack them in different environments.	2.0	2.6	4.6

Lines of Work	Man-Years Federal	State	Total
Involves studies on morphological characteristics of specific range weeds and environment in relation to the development of host plant selectivity and specificity of insects considered as potential biological control agents.			
3. Competition between weeds and desired plants and plant successions following control measures including replacement vegetation and management measures.	8.7	11.3	20.0 1/
Involves studies on plant ecological shifts following weed control measures; the effectiveness of reseeding pastures and ranges and management practices in suppressing weeds; the effectiveness of different forage species in suppressing weeds when planted after weed destruction by chemical, biological, mechanical, or combination weed control measures.			
4. Evaluation of genetic potential for increasing tolerance of crop plants to herbicides.	0.2	-	0.2
Involves limited and scattered studies and observations on the tolerance of breeding lines and varieties of different crop plants to herbicides; and variations in response of different biotypes of weed species to selected herbicides.			
5. Spread of weeds through transportation and marketing channels	-	-	-
No planned research is underway on this problem.			

1/ Includes approximately 11 man-years on management and reseeding aspects of weed control.

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
6. Legal and regulatory activities	-	-	-
Some regulatory work is being done to prevent spread of weeds such as witchweed, but no planned research is underway to evaluate the legal and institutional aspects of weed control to provide bases for making public decisions relating to weed control programs.			
7. Effects of weed control measures on the ecology and environment of fish and wildlife.	1.0	-	1.0
Includes limited studies on the effects of burning of forest ranges and other weed control measures on cover and food for wildlife; and the acute toxicity to fish of selected aquatic herbicides.			
8. Evaluation of weed damages, values and benefits of control	5.0	5.0	10.0
Involves studies on the economics of weed control in relation to range problems; damages to crop yields and quality of plant products by weeds and economic benefits from weed control measures.			
	(19.7)	(21.5)	(41.2)
Subtotal Item I	(59.9)	(65.3)	(125.2)

Lines of Work	Man-Years Federal	State	Total

II RESEARCH THAT APPLIES TO WEED CONTROL IN SPECIFIC CROPS OR SITUTATIONS

Development of safe and economical methods and equipment for weed control, including chemical, cultural, and biological methods, and integration of control measures into efficient management systems.

A. In agronomic crops

Involves largely research to develop practical weed control measures including the evaluation of the weed control effectiveness and crop plant reactions to newly introduced herbicides when applied at different dosages as pre-planting, pre-emergence, and post-emergence treatments; improve herbicide application equipment and mechanical weed control equipment; compare chemical, cultural, mechanical, and combination methods for controlling weeds selectively; determine effects of chemicals used for weed control on succeeding crops and associated weeds; evaluate effects of herbicides on the germination of seeds of and quality of treated agronomic crops; and measure the effects of natural environmental factors on the performance of herbicides.

Present manpower devoted to the types of studies listed is given below:

Lines of Work	Federal	State	Total
1. Cereal crops			
a. Corn	2.1	7.0	9.1
b. Sorghum	0.7	2.3	3.0
c. Small grains	2.2	7.3	9.5
2. Cotton	3.8	4.7	8.5

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
3. Oilseed crops			
a. Soybeans	2.1	2.4	4.5
b. Peanuts	0.4	1.6	2.0
c. Others (safflower, castor beans, sesame, flax)	0.2	1.3	1.5
4. Sugar crops			
a. Sugarcane and sweet sorghum	1.0	2.8	3.8
b. Sugar beets	0.8	0.4	1.2
5. Tobacco	-	0.4	0.4
	(13.3)	(30.2)	(43.5)

B. In horticultural crops

Involves limited research to develop practical chemical and combination control measures for the most critical weed problems including the evaluation of promising new herbicides for the selective control of weeds in vegetables, fruit and nut crops, and ornamentals; determination of the effects of climate, cultural practices, soil composition, formulation, time of application and varietal differences on the performance and persistence of herbicides; comparisons of chemical, mechanical, and combination methods of weed control, including limited studies on long-term effect of repeated applications of herbicides on perennial small fruit and orchard crops.

The professional manpower presently devoted to studies such as those listed is as follows:

	Federal	State	Total
1. Vegetable crops			
a. Legume crops	0.4	1.9	2.3
b. Vine crops	0.6	1.4	2.0

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
c. Solanaceous crops	0.7	1.9	2.6
d. Leaf, salad, and cole crops	0.4	1.5	1.9
e. Root and bulb crops	0.4	2.0	2.4
2. Fruit and nut crops			
a. Small fruit crops	0.2	2.0	2.2
b. Orchard fruit crops	0.2	2.2	2.4
c. Orchard nut crops	-	1.6	1.6
3. Ornamental crops			
a. Bulb crops	0.1	0.7	0.8
b. Perennial herbaceous crops	-	0.7	0.7
c. Perennial woody crops	0.1	2.4	2.5
d. Herbaceous annuals	-	0.7	0.7
	(3.1)	(19.0)	(22.1)

C. In forage, pasture, and rangelands

Involves evaluation of cultural (including burning) and management practices and herbicides for controlling weeds; studies of influence of herbicide formulation, and date, rate and method of application on effectiveness of chemical weed control procedures and combinations of established practices with new methods; determination of weed and desirable plant responses, ecological shifts in weed populations, and evaluation of the place in the management system of use of improved chemical or other weed control methods; establishment and management of replacement vegetation to suppress weeds; and determination of the effectiveness of insects in controlling specific range weeds.

Lines of Work	Man-Years Federal	State	Total
Present professional manpower devoted to the lines of work listed are estimated as follows:			
1. Native and established permanent pastures	3.4	3.0	6.4
2. Rangelands	7.0	4.5	11.5
3. Forage grown for hay	0.8	2.0	2.8
4. New seedings of forage crops	1.2	0.8	2.0
	(12.4)	(10.3)	(22.7)

D. In crops grown for seed production

Involves studies on the use of herbicides, cultural practices, and other techniques for controlling weeds, including volunteer crop plants, inforage legume and grass seed production fields; limited evaluation of selected promising herbicides for control of dodder in alfalfa seed fields.

Present professional manpower devoted to the work listed is as follows:

	Federal	State	Total
1. Agronomic crops			
a. Forage legumes	1.0	1.2	2.2
b. Forage grasses	0.4	0.6	1.0
c. Turf grasses	-	0.4	0.4
2. Horticultural crops			
a. Vegetables	-	0.2	0.2
b. Ornamentals	-	0.1	0.1
	(1.4)	(2.5)	(3.9)

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
E. For timber stand and forest-range improvement			
Includes studies on the use of herbicides known to be effective brush killers, to eliminate undesirable trees and brush in timber stands, including use of aircraft and other equipment for treatment of large forested areas with herbicides; measurement of benefits of removing undesirable vegetation from the forests by hand, mechanical, and standard chemical treatments; use of fire to kill or suppress weeds, including brush on forest rangelands, and the recreational and wildlife values and damages resulting from weed control measures; ecological shifts in weed populations following different management practices.			
Present professional manpower devoted to the work listed is as follows:			
1. Timber stand improvement, forest type conversion, and site preparation	15.2	1.6	16.8
2. Forest rangeland improvement	2.2	0.6	2.8
	(17.4)	(2.2)	(19.6)
F. For irrigation, drainage and other waters	6.6	3.9	10.5
Involves studies on the evaluation of different forms of promising herbicides for their effectiveness in killing submersed, floating, and emerged aquatic weeds in irrigation and drainage systems, and in certain other waters; determination of the effects of water temperature, chemical composition, silt content, depth of water and velocity of flow on the efficiency of herbicides in killing aquatic weeds; and evaluation of ecological shifts in aquatic weed species following control measures.			
	(6.6)	(3.9)	(10.5)

Lines of Work	Man-Years Federal	Man-Years State	Man-Years Total
G. For weed infested areas adjacent to crop lands	0.6	4.2	4.8
Involves limited work to determine the effectiveness of different soil-sterilant, selective, and non-selective herbicides in controlling weeds on noncrop areas such as ditchbanks, fence rows, equipment-storage areas, and rights-of-way through farms.	(0.6)	(4.2)	(4.8)
H. In lawns and turf	0.4	3.9	4.3
Involves scattered work on the evaluation of herbicides for controlling crabgrass and other weeds selectively in lawns, including management to encourage competition from desirable species to suppress weed growth.	(0.4)	(3.9)	(4.3)
I. Special weed problems	4.1	8.0	12.1
Involves work directed toward the control of specific weeds such as witchweed, Johnsongrass, Canada thistle, field bindweed, nutsedge, halogeton, dodder, water stargrass, alligator weed, quackgrass, pond weed, mesquite, oak and juniper.	(4.1)	(8.0)	(12.1)
Subtotal Item II	(59.3)	(84.2)	(143.5)
Total	119.2	149.5	268.7

RESEARCH NEEDS

Research needs on the weed control problem arbitrarily have been divided in this report into two main categories, I. Basic weed control research that applies to most crops and situations, and II. Research that applies to weed control in specific crops or situations. The first category involves investigations on general biological principles that have application to many crops or weed species or many sites or situations in which the plants occur. The second category involves research that is aimed at the development of weed control practices in specific crops or situations. Such research also involves the integration of control measures into efficient management systems.

It should be emphasized that the two categories of research must be closely integrated. Research in the second category, in broad terms, consists of incorporating the basic principles, developed in the first category, into practical control measures. It is also worthy of note that research in the basic category utilizes plants and situations enumerated in the second category and, in the course of investigating principles, much information that applies to specific crops, weeds or situations is obtained.

I BASIC WEED CONTROL RESEARCH THAT APPLIES TO MOST CROPS AND SITUATIONS

The introduction of 2,4-D, 2,4,5-T and MCPA as selective herbicides about 15 years ago stimulated the initiation of a rather extensive program of applied research on herbicides to attack immediate critical weed problems. Applied chemical weed control research conducted by many industrial, State, and Federal weed research scientists has made great progress in reducing production costs of several important crops. Applied weed control research programs during the past decade have brought to light many questions which can be answered only by a vigorous program of basic research. Many weeds cannot be killed by present chemicals, and information is largely lacking as to why a herbicide will kill one plant but not another. Movement and accumulation of herbicides in plants, soils, and water are not understood. A more exact knowledge of the mechanisms involved in conditioning leaf, stem, and root surfaces for efficient penetration by herbicides and in their movement after penetration is needed to provide a sound basis for the development of practical and reliable procedures for using herbicides to control weeds. The nature of herbicide residues occurring in food and feed and their importance to human and animal health have not been accurately determined. Fundamental knowledge about the life histories of weeds and their ecological relations to desirable plants and natural enemies in different climatic zones is inadequate. Basic information on problems such as those listed must be obtained to insure the continued development of improved, more economical, and safe weed control measures. Equally important are the needs for discovery of principles that will open new frontiers for practical development.

[illegible]

Research needs on the weed control problem area currently have been divided in this report into two main categories, i. Basic weed control research that applies to most crops and situations, and ii. Research that applies to weed control in specific [illegible] situations. The first category involves investigations on general biological principles that have application to many crops or weed species or many sites or situations in which the plants occur. The second category involves research that is aimed at the development of weed control practices in specific crops or situations. Such research also involves the integration of [illegible] measures into efficient management systems.

It should be emphasized that the two categories of research must be closely integrated. Research in the second category, in broad terms, consists of incorporating the basic principles, developed in the first category, into practical control measures. It is also worthy of note that research in the basic [illegible] utilizes plants and situations encountered in the second category [illegible], in the course of investigating principles, much information that applies to specific crops, weeds or situations is obtained.

BASIC WEED CONTROL RESEARCH THAT APPLIES TO MOST CROPS AND [illegible]TIONS

The introduction of 2,4-D, 2,4,5-T and MCPA as selective herbicides about 15 years ago stimulated the initiation of a rather extensive program of applied research on herbicides to attack immediate critical weed problems. Applied chemical weed control research conducted by many industrial, State, and Federal weed research scientists has made great progress in reducing production costs of several important crops. Applied weed control research progress during the past decade have brought to light many questions which can be answered only by a vigorous program of basic research. Many weeds cannot be killed by present chemicals, and information is largely lacking as to why a herbicide will [illegible] one plant but not another. Movement and accumulation of [illegible] in plants, [illegible]le and water are not understood. A more [illegible] knowledge of the [illegible] involved in conditioning leaf, stem, [illegible] for [illegible] foliar penetration by herbicides and in their [illegible] [illegible]rol is needed to provide a sound basis for the [illegible], at present [illegible] and reliable procedures for using herbicides [illegible] of weeds. The nature of [illegible] residues occurring in food [illegible] systems [illegible]

[illegible] of weeds and their [illegible] [illegible] species in different climatic zones [illegible] on problems such as those listed must be obtained to insure the continued development of improved, more economical, and safe weed control practices. Equally important are the needs for discovery of principles [illegible] will open new frontiers for practical development.

A. Evaluation of chemicals and insects and other biological agents for weed control

Many weed species are not controlled by available herbicides. Weeds in many crops and situations cannot be controlled economically because present herbicides are too toxic to the crop plants or fail to kill selectively the important weed species. Chemical or mechanical methods cannot be used for weed control on extensive low-producing rangelands and watersheds because of prohibitive costs. More effective and economical chemical, mechanical, biological, cultural, or combination methods of controlling weeds associated with crop plants, in grazing lands, in noncrop areas, and in water supplies and drainage systems are needed.

Introduction and evaluation of new chemicals having various herbicidal properties have been providing and will continue to provide the primary source of energy for developing new and improved methods of weed control. Insects and other biological agents have in some instances reduced certain weed populations to largely noninjurious levels. Biological agents are urgently needed to control introduced weeds particularly in extensive rangelands and aquatic sites where chemical methods are impracticable.

To meet the needs listed the following lines of work are proposed:

1. Development of new evaluation techniques and equipment to measure simply, rapidly, and accurately the differential herbicidal and other effects of new chemicals and biological agents on a wide variety of weeds and crop plants.

2. Search for new and more effective agents. Large numbers of chemicals shown to possess phytocidal properties or, because of their chemical configuration are deemed to possess them, should be systematically evaluated. In most cases the Department looks to the chemical industry for the synthesis and screening of chemicals for herbicidal activity. However, in cases where potential usage is primarily for crops with limited acreages, like okra, or for specific troublesome weeds on currently restricted areas, like witchweed, where potential volume of sales is insufficient to warrant major attention by industry, the Department should evaluate new chemicals and determine their effectiveness.

   An extensive search should be made, particularly in foreign countries, for new and suitable insects, fungi, bacteria, viruses, and other biological agents that might eradicate

or control specific weeds in the United States. Promising agents should be identified and their effectiveness in controlling weeds determined. Painstaking laboratory and field studies in the native homes of such agents are necessary to determine whether their introduction and liberation might be inimical to American agriculture.

3. Determinations of activity and selectivity of agents including relation of molecular configurations to the herbicidal activity and selectivity of chemicals. Such information will be made available to scientists in industry and public agencies to aid in the design of new chemicals having greater efficiency as herbicides. The climatic, physical, biological, and other forces that govern host selection and specificity of phytophagous (herbivorous) insects and other biological agents should be determined.

B. Determination of nature, behavior, and effects of herbicides and their degradation products

Present herbicides are effective in destroying both top and root growth of many weeds but, when applied to numerous other herbaceous and woody weeds, kill only the top portions or cause no perceptible damage. A particular herbicide may effectively control weeds on some sites but fail to control the same weeds on other sites or under different soil and environmental conditions. Herbicides injure or kill certain crop plants under some circumstances but not under others. The reasons for erratic and differential effects of herbicides on plants are not established.

Several stable and persistent herbicides are being used annually on large acreages of cropland, and information is largely lacking on possible accumulation and long-term effects of these chemicals on existing perennial crops, succeeding crops, and soils. The rate of accumulation and disappearance of herbicides in plants, animals, soils, and water, and the degree of metabolism or degradation of herbicides in and on plants, and animals are largely unknown. Farmers may be denied the use of some herbicides in wide usage today because of the lack of an understanding of the amount and nature of herbicide residues which may subsequently occur in parts of the plant eaten by humans or in milk or other products from animals that eat the treated plants.

Information on the toxic effects on fish and wildlife and their natural food sources of herbicides being used or developed for weed control in irrigation, drainage, and other waters and in wildlife habitats is wholly inadequate.

Development and safe use of more effective and economical new herbicides depend on understanding the entry, movement, accumulation, persistence, and fate of herbicides in and on plants and plant products, in and on soils, in irrigation, drainage, and other waters, and in and on animals and animal products. Also the identity and importance of degradation products resulting from physiological, chemical, photochemical, and other physiochemical reactions must be understood. Such basic information is prerequisite to formulating safe recommendations on the use of promising herbicides and to exploiting adequately the potentials of synthetic organic chemicals for combatting weeds more efficiently without fear of harm to crop plants and to men and animals that eat them.

1. In and on plants and plant products

   a. Absorption, penetration, translocation, persistence, and accumulation of herbicides and degradation products in plants and plant products, including animal feed as influenced by chemical structure, formulation, environment and other factors should be determined.

   b. Mechanisms by which herbicides affect plants differentially including the influence of plant species, varieties, and weed biotypes, and chemical, physical, physiological, and morphological factors should be determined.

   c. Metabolism and degradation products of herbicides, the biochemical and physiological processes involved, and the influence of environment, plant species, and other factors should be determined.

   d. Influence of environmental factors such as temperature, light, and moisture on evaporation and deactivation of herbicides on plant surfaces and the effects of environment on penetration, translocation, and herbicidal activity of selected compounds should be understood.

   e. Influence of formulation and time and method of application on the form and amount of residues of selected herbicides in organs and parts of different species and varieties of plants should be studied. Sensitive analytical methods for the quantitative detection and identification of traces of herbicides and their degradation products in and on plant tissues must be developed.

f. Effects of herbicide and other weed control measures on chemical composition and quality of the crop plants and plant products should be determined.

2. In and on soils in relation to weed control and crop production

a. Movement and persistence of herbicides and phytocidal activity of herbicides in different soils, as influenced by herbicide formulation and dosage, time and method of application, rainfall, temperature, soil aeration, crop rotation, and other factors should be known. Development of biological and chemical methods of isolating and identifying herbicides and their breakdown products in soils is necessary.

b. Interactions of herbicides with soil, and the absorption-desorption energy relations, chemical deactivation, and nature and extent of microbial and chemical inactivation should be studied. Knowledge of the reactivity of herbicides with soil constituents and their retention in active and inactive forms as well as the effects of herbicides on nutrient availability and on soil microflora and the influence of soil microflora on herbicides is necessary. Research on the compounding of fertilizer-herbicide mixtures also is needed.

c. Ultimate fate of herbicides in soils as influenced by volatilization and photoinactivation on soil surfaces, chemical and biological degradation, adsorption and absorption by soil particles, uptake by plants from soils, and other processes should be determined.

d. Form and amount of herbicide residues and their degradation products on and in soils following applications by different methods and at varying dosages and times to soils under various environmental conditions should be investigated.

3. In irrigation, drainage, and other waters

Methods for the quantitative detection of traces of herbicides and their degradation products should be developed and persistence of herbicides as influenced by biological, physical, and chemical properties of water measured. Effects of formulation, dosage, and time and method of application on the disappearance of herbicides from waters should be

investigated, including the effects of herbicides in irrigation water on crop plants and the ultimate fate of the chemicals. Movement and persistence of herbicides in bottom mud of water impoundments and conducting systems should be studied in relation to weed control effectiveness. The investigations listed would apply to irrigation, distribution, and drainage systems; lakes, ponds, and reservoirs; meadows, marshes, and swamps; and to streams, rivers, and estuarine waters.

4. In and on animals and animal products

Metabolism and degradation, in animals, of herbicides in and on feed and forage should be studied; acute and chronic effects of selected herbicides on domestic and wild animals should be explored; herbicide residues in and their effects on animal products such as milk, meat and eggs, and fish and game, should be measured with emphasis on determination of such residues following practical application of the herbicides.

C. Development of principles of mechanics of herbicide application and weed seed removal

1. Herbicide deposits on plants and in the soil including particle size and mass distribution

Evaluation and introduction of chemicals with herbicidal properties have greatly expanded the possibilities of better weed control. However, a large part of the herbicides applied are wasted because of inability to control placement. Herbicide-application efficiencies have usually been evaluated in terms of plant control because mass-deposit measurement is very difficult. Limited measurements of dust-type pesticide materials, however, have indicated application efficiencies as low as 10 to 15 percent. Drift of herbicide particles is frequently a hazard to adjacent crops and sometimes precludes the use of economical and labor-saving chemicals for weed control. Better control of placement would help reduce costs, reduce residues, and minimize damage to desired plants.

2. Mechanics of forces affecting particle deposition, and characteristics of special formulations such as granules, inert emulsions, and volatile materials

Although much progress has been made in herbicide application equipment, most present machines and techniques are primarily empirical developments. Basic research is

investigated, including the effects of herbicides in irrigation water on crop plants and the ultimate fate of the chemicals. Movement and persistence of herbicides in bottom mud of water impoundments and conducting systems should be studied in relation to weed control effectiveness. The investigations listed would apply to irrigation, distribution, and drainage systems: lakes, ponds, and reservoirs; marshes, swamps; and to streams, rivers, and estuarine waters.

In and on animals and animal products

Metabolism and degradation, in animals, of herbicides in and on feed and forage should be studied; acute and chronic effects of selected herbicides on domestic and wild animals should be explored; herbicide residues in and their effects on animal products such as milk, meat and eggs, and fish and game, should be measured with emphasis on determination of such residues following practical application of the herbicides.

Development of principles of mechanics of herbicide application and weed seed removal

Herbicide deposits on plants and in the soil including particle size and mass distribution

Evaluation and introduction of chemicals with herbicidal properties have greatly expanded the possibilities of better weed control. However, a large part of the herbicides applied are wasted because of inability to control placement. Herbicide-application efficiencies have usually been evaluated in terms of plant control because deposit measurement is very difficult. Limited measurements of dust-type pesticide materials, however, have indicated application efficiencies as low as 10 to 15 percent. Drift of herbicide particles is frequently a hazard to adjacent crops and sometimes precludes the use of economical and labor-saving chemicals for weed control. Better control of placement would help reduce costs, reduce residues, and minimize damage to desired plants.

[illegible]

[illegible] has been made in herbicide application [illegible] machines and techniques are [illegible] developments. Basic research is

proposed on the effects of physical forces (gravitational, inertial, thermal, and electrical) which control the deposition of herbicide particles. The basic studies on their behavior will furnish information for the development of guiding principles for the design of equipment that will control more accurately the amount and location of material applied. More accurate control will lead to more specific and uniform application of smaller amounts of material for a given degree of control or to improved control with the same amount.

3. New principles, equipment, and techniques for removing weed seeds during on-the-farm and commercial cleaning

   A problem of paramount importance to present-day agriculture is the availability of clean, pure planting seeds. Various drillbox surveys have revealed that many farmer-cleaned planting seeds are infested with noxious weed seeds. In one survey, for example, 85 percent of 350 samples contained noxious weed seeds.

   The research program needed is concerned with the development of equipment and methods for more efficient removal of weed seeds from crop seeds for both domestic and foreign consumption and by both farmer and commercial cleaning. Research is needed to develop better means of separating weed seeds from desirable ones during harvesting.

D. Determination of weed characteristics and weed control in relation to desired plants and the feasibility of control practices under different conditions

The methods used in controlling any weed must be related to its habits of growth and reproduction. Weeds most commonly reproduce by means of seed but some, especially perennials, can spread vegetatively. Some seeds germinate primarily during specific seasons, while others germinate under a wide range of conditions. To be successful control practices must be correlated with such weed characteristics.

Insects, plant disease organisms, and other plant-attacking organisms are known to have preferred host plants. The host plants may be more or less susceptible to attack under different growing conditions including those influenced by competing plants in the same area. Much of the permanent pasture and rangeland areas in the United States support livestock far below their potentials. In these areas weed control, although essential, must be followed by proper revegetation and management practices.

Some crop plants have shown a potential for developing genetic lines with increased tolerance to certain herbicides. Genetic tolerance in crop plants to widely accepted herbicides, if found feasible to develop, would have definite advantages.

Importation and transportation of weed seeds or plants are not controlled because of the lack of adequate research information on which to formulate regulations. The benefits of legal programs designed to enlist community-wide participation in weed-control programs need consideration.

Weed control by chemicals may have a direct effect on wildlife occupying the area treated, by eliminating sources of food or rendering the food unsuitable. Control measures may lower rates of reproduction of birds, such as quail, without any apparent deleterious effect on the living birds. On the other hand,killing the tops of some kinds of trees promotes desirable basal sprouting and increases deer browse.

There can be no doubt that most weeds add to the cost of raising crops, but insufficient information is available to determine the magnitude of this cost or the economic benefits to be drived from improved methods of control. Furthermore, certain weeds that grow in forages have an apparently measurable benefit to the animals that feed on them. Weeds that grow in tillable land at times reduce water and wind erosion of soils. Some weeds, such as poison ivy, poison sumac, and ragweed cause marked discomfort to man. Needed lines of research are enumerated.

1. Life cycles and growth habits of weeds under different environments, including their susceptibility to control agents at different stages and the germination and longevity of weed seeds

   Life cycles and growth habits of weeds, including brush, should be studied under different environments because under different conditions one weed may be an annual or a biennial and another may produce seed or reproduce vegetatively. The mechanisms that control longevity and germination of weed seeds including methods for artifically stimulating germination need study. The stages in their life cycles when weeds are most susceptible to control by chemicals or other means should be determined.

[illegible]

[illegible]

[illegible] of legal programs designed to enlist community-wide participation in weed-control programs need consideration.

Weed control by chemicals may have a direct effect on wildlife occupying the [illegible], by eliminating sources of food or rendering [illegible] unfit [illegible] may lower rates of reproduction of birds, such as quail, without any apparent direct toxic effect on the living birds. [illegible] the [illegible] weed, killing the tops of some kinds of trees [illegible] basal sprouting and increases deer browse.

[illegible] be no doubt that most weeds add to the cost of [illegible], but insufficient information is available to [illegible] the [illegible] of this cost or the economic benefits [illegible] improved control [illegible]. Furthermore, [illegible]

[illegible] weed and [illegible] at times reduce water and wind erosion of soils. But weeds, such as poison ivy, poison sumac, and ragweed cause [illegible] discomfort to man. Recent [illegible] research [illegible] are summarized.

[illegible] Life cycles and growth habits of weeds under different [illegible] including their susceptibility to control [illegible] and [illegible]

[illegible]

2. Relations between weeds and the biological-control agents that attack them under different environments

The relations between weeds, both native and introduced, and the insects, disease-producing organisms, or other living organisms that attack them in different areas and under different conditions should be studied. These biological agents should be classified and their distribution determined. The possibilities of synchronizing the time they attack with the stage in the life cycle of the plant when it is most susceptible to attack should be investigated.

3. Competition between weeds and desired plants and plant successions following control of weeds including replacement vegetation and management measures

The ability of weeds and beneficial or desired plants to compete successfully in permanent pastures and rangelands should be investigated to determine the basic principles for successful biological control to aid in proper land management. Many programs aimed at brush and weed control require companion research on seeding or other revegetation practices to provide information needed for establishment of desirable replacement vegetation on sites freed of weeds and brush. Basic ecological studies are needed to determine plant successions under both undisturbed and cultivated situations following various weed control and management practices.

4. Evaluation of genetic potentials for increasing tolerance of crop plants to herbicides

Marked differential reaction of varieties of several species of crop plants to specific herbicides has been noted. Sweet corn hybrids differ widely in their tolerance to 2,4-D and sugar beet varieties differ with respect to damage by endothal and TCA. Because the development of crop varieties highly tolerant to effective and widely used herbicides would permit development of weed-control practices with still greater effectiveness, limited exploratory breeding of several crops has been initiated.

Determination of the fundamental genetic potential for increasing tolerance of crop plants to specific herbicides known to have wide acceptability is needed for the guidance of the numerous crop-breeding programs.

5. Spreading of weeds during transportation and marketing

Transportation and marketing channels constitute one of the chief avenues for the spread of weeds. The difficulties of the problem and its solution with presently available conventional equipment are shown by the fact that tolerance for some types of weed seeds are permitted in most certified seed sold and traded inter- and intra-state. In some states the presence of certain noxious weed seeds and the cost of cleaning to certification standards prohibit the growing of some seed crops for sale. Each year a large number of shipments of seeds that do not meet regulatory standards are seized and condemned by inspectors.

Research is needed to determine when and where the movement of weed seeds and plant materials should be regulated in transportation and marketing channels, and what kinds of controls are necessary and feasible. Equipment, techniques, and procedures to remove the weed seeds or otherwise to prevent their movement in feed grains, hay for feed, manure, top soil, and nursery stock must be studied. Research also should include ways and means for killing weed seeds in infested material before distribution.

6. Legal and regulatory activities

Public decisions with respect to weed control are often needed. Economic and legal appraisals of the problem, the costs and effectiveness of public action, methods of financing, benefits to be expected, legal tools needed for action, and other factors studied will assist in arriving at sound public decisions.

A study of legislation dealing with restrictions of weed movement reveals that neither the Plant Quarantine Act of 1912, as revised, nor the Federal Plant Pest Act of 1957 gives the Secretary of Agriculture authority to refuse importation or interstate movement of plants or their seeds because they are in the plant category known as "weeds" or because they may become weeds under United States conditions. Further, although the Federal Seed Act of 1939 as revised empowers the Secretary to refuse seed importations found contaminated with specified quantities of seeds of weeds defined as "noxious", the limitations imposed are not adequately restrictive. In small seeds, for instance, up to 45 noxious weed seeds may be imported per pound of crop seed.

An example illustrating presently needed control research, and possibly regulatory authority, is furnished by alfombrilla (Drymaria arenarioides), a plant poisonous to animals and presently found in Mexico within seven miles of the New Mexico border. Under present regulations importation of seed or plants free of soil or disease cannot be prohibited. The Mexican government, with support from the Rockefeller foundation, is doing some work on chemical control. Biological control measures seem to be logical since the plant normally occurs on dry, low-value range areas where other methods appear to be excessively costly.

Studies should include legal-economic studies of noxious weed control laws and government programs and operation. They should include studies of the economic feasibility of weed control districts and other public means including adequacy of authority, methods of financing, and benefits to be expected. Also included would be an economic appraisal of weed problems in relation to the need for public action.

7. Effects of chemical and other weed control measures on the ecology of fish and wildlife

The effect of chemical and other weed-control practices on fish and wildlife, and on their environment, should be measured to determine whether better or poorer ecological conditions result, i.e. whether the wildlife-carrying capacity of areas in which control measures are practiced is raised or lowered.

8. Evaluation of weed damages and values and benefits of control

Losses resulting from weed infestations should be evaluated to determine the economic effects of weed control on total output and productivity of agricultural areas. The extent, methods, and costs of present control practices should be studied, and net benefits of control programs and rates of adoption of innovations in control practices should be assessed. The nutritive value of weeds and weed-forage mixtures that commonly occur in pastures or hays should be examined to determine the feed values as compared with those of non-weed-infested fields. The role of weeds in suppressing soil erosion and in causing water losses in tilled crop and grazing lands should be determined. The importance of weed control in the reduction of human discomfort from poisonous plants and others that cause allergies should be considered.

II RESEARCH THAT APPLIES TO WEED CONTROL IN SPECIFIC CROPS OR SITUATIONS--
Development of safe and economical equipment and methods for weed control including chemical, cultural (including burning), and biological methods, and integration of control measures into efficient management systems.

Environmental conditions, cultural practices, and natural distribution of weed species are critically important in developing safe and economical methods and equipment for weed control. Rainfall, temperature, solar radiation, wind velocity, and other climatic factors in the environment have profound effects on the growth and development of weeds and crop plants and on the performance, selectivity, and persistence of herbicides. The amount and incidence of rainfall narrowly limit the effectiveness of many herbicides. Photodecomposition due to high sunlight radiation is important in the breakdown of certain herbicides. Temperature and wind velocity are particularly important in the performance of vaporactive herbicides such as carbamates. Soil composition affects the performance of certain herbicides and the cultural practices and mechanical methods that can be used effectively in controlling weeds. The amount and time of irrigation affect the development of weeds and the performance and persistence of herbicides.

Weed species vary widely in large geographical areas characterized by high-temperature, long-season conditions as compared with those in areas characterized by arid and semi-arid conditions. Annual- and perennial-weed problems also vary widely with the crops and the cultural techniques used. Certain weeds are serious problems in specific geographical areas. For example Johnsongrass, nutsedge (nutgrass), and Bermudagrass are problems in the Southwest, South, and Southeast. Quackgrass, foxtail, and other weeds are problems in the Northeast and Northcentral states, whereas cheatgrass, dodder, halogeton, juniper, mesquite, oaks, sagebrush, wild oats, and other weeds are problems in the western United States. In addition these and other weeds frequently occur in different crops in different soil and climatic areas and each of the crops and areas may require special investigations for the development of safe and economical control measures.

A. In agronomic crops

Yield reductions incurred by weeds and costs of control in the eleven principal agronomic crops were estimated to approach $2 billion annually in a study made in 1954 by the Agricultural Research Service, U. S. Department of Agriculture, in cooperation with other Departmental and Federal Agencies. Increased mechanization of crop production, accompanied by inadequate hand labor, in recent years has accentuated the

weed problem and partially offset improved control practices. Eager to reduce losses caused by weeds, American farmers are adopting chemical weed control methods in advance of the development of adequate research information to insure the safety of their use. Weeds in many crops cannot be controlled satisfactorily by present measures and the cost of using hand labor for weeding some crops has become so prohibitive that farmers are forced to adopt alternative enterprises as sources of income. Increased research is needed to develop improved chemical methods, and combination chemical, cultural, and biological methods of weed control are needed to permit increased mechanization, to lower production costs, and to improve crop quality and yields.

1. Cereal crops

   a. Corn--Significant progress has been made in controlling annual broadleaved and grassy weeds in corn. However, present chemical, cultural, and mechanical methods are not efficient for destroying certain troublesome weeds such as witchweed, quackgrass, nutsedge, smartweed, field bindweed, and Johnsongrass. Chemical and cultural methods for controlling weeds that emerge with corn are erratic, and herbicide-tolerant weeds are increasing in corn areas where 2,4-D has been used increasingly for controlling established broadleaved weeds. Some of the long-persisting new herbicides are being used on large corn acreages where residual buildup of the materials in the soil may preclude for one year or longer the use of the land for production of other crops.

   b. Sorghum--Weeds such as Johnsongrass, field bindweed, ragweed, foxtail, morning-glory, pigweed, and others are increasing in sorghum-producing areas each year. The rainfall, soil, and general climatic conditions in the major sorghum-growing areas make especially difficult the development of safe, efficient, and economical chemical methods for selective control of weeds in sorghum. Intensified work is needed to develop economical weed control methods.

   c. Small grains--Some weedy grasses cannot be controlled in wheat, oats, barley, and other small grains with present chemical, cultural, and mechanical methods. Recently herbicides have been introduced by industry that show good promise for controlling wild oats in

wheat and barley but not in oats. Herbicides such as 2,4-D are being used effectively to control susceptible broadleaved weeds in nearly 20 million acres of small grains not underseeded with legumes. Some herbicides have shown promise for selectively controlling certain weeds in small grains underseeded with legumes such as alfalfa, red clover, white clover, lespedeza, and birdsfoot trefoil, but the compounds are expensive and the inadequacy of residue data precludes their use in the United States at present. Canada thistle, field bindweed, wild buckwheat, wild garlic, wild oats, weedy bromegrasses, and milkweed infestations are increasing in small grains. Weed control measures are particularly needed for water conservation in areas where stubble mulch tillage and fallow systems are practiced. In a recent survey by the Department of Agriculture, 11 states indicated that present weed control measures in small grains are only fair and 14 indicated an urgent need for improved methods. Research is needed to develop new principles and methods of reducing the losses caused by weeds in small grains.

2. Cotton

Pre-emergence herbicides are being used with good success on almost 1 million acres of cotton in the Lower Mississippi Valley to control early season annual weeds but climatic and soil conditions render these materials ineffective in the Coastal Plains, High Plains, and in irrigated valleys of the West. Present chemical and cultural methods are not efficient in controlling Johnsongrass, nutsedge, redvine, trumpet vine, and other perennial weeds. Infestations of these weeds continue to increase and cause damage to cotton yields and quality.

Grasses which germinate after the last cultivation of cotton are not controlled satisfactorily by present methods and they are becoming increasingly serious as more cotton acreage is irrigated supplementally in the humid and semi-humid cotton belt. Increased work is needed in the major cotton-growing areas to develop improved pre-planting, pre-emergence, and post-emergence chemical and other methods of controlling weeds in cotton that leave no harmful residues in cotton or cotton soils and that do not fluctuate erratically with variations in environment and soil. In a recent survey by the Department 11 states indicated a critical need and 2 an urgent need for improved weed control methods in cotton.

3. Oilseed crops

a. Soybeans--There are no completely satisfactory chemical methods of controlling weeds in soybeans and cultural and mechanical measures in use are relatively inefficient in reducing weed losses, estimated as high as $200 million annually. Crabgrass, cocklebur, coffeeweed, foxtail, Johnsongrass, pigweed, and others continue to spread in soybean-growing areas and cause moderate to heavy damage to yields and quality. Annual morning-glory and crotalaria seed in harvested soybeans have serious adverse effect on the domestic and foreign markets. Eleven of 15 states recently surveyed by the Department indicated an urgent need and 4 a critical need for improved weed control measures for soybeans. Research is needed to develop safe and economical chemical, cultural, and combination weed control methods adapted to the soil and climate of the major soybean-producing areas.

b. Peanuts--Some progress has been made in using herbicides on a limited scale. Although present herbicides are fairly effective in weed control, some injury to the peanut plant is sustained. However, the benefits of weed control usually more than offset crop damage. Present chemical methods are not efficient for controlling troublesome weeds such as Bermudagrass, crabgrass, goosegrass, nutsedge, pigweed, purslane, and sandbur. Weed control methods involving cultivations to cover weeds with soil promote the incidence of southern blight (Sclerotium rolfsii), a disease which reduces yield and quality of peanuts. Recent research has shown that the use of chemicals for weed control instead of cultivation greatly reduces the disease incidence and results in better yields and quality. Research is needed to develop and improve chemical and combination chemical-cultural methods for controlling weeds in peanuts.

c. Safflower, castorbeans, sesame, flax, and other oilseed and industrial crops--The value of safflower, castorbeans, sesame, and others as new or substitute crops for surplus commodity crops has been demonstrated. The introduction and economic production of these crops are threatened seriously by the lack of efficient and economical methods of controlling weeds. Research is urgently needed to develop chemical weed control

measures and combination methods which do not leave residues in the crops or soils and are not adversely affected by variations in environment and soil.

4. **Sugar crops**

a. Sugarcane and sweet sorghum--Although herbicides are being used in sugarcane, their effectiveness is limited where troublesome weeds such as Johnsongrass, Bermudagrass, and alligator weed occur. Weeds in sugarcane reach especially serious proportions because the row in which the crop grows cannot be cultivated efficiently throughout the 3-year life span of sugarcane. Moreover, sugarcane grows in areas with mild climate and high rainfall and certain species of weeds grow throughout the year. Sweet sorghum also is grown in areas where the climatic and soil conditions favor unusually vigorous growth of weeds from planting time until harvest. Annual morning-glory, Bermudagrass, crabgrass, Johnsongrass, nutsedge, and pigweed are particular problems in sweet sorghum. Research is needed to develop combination chemical and cultural methods for controlling weeds which do not leave residues in the crops or soils and are not adversely affected by variations in soils and climate.

b. Sugar beets--Present weed control methods during the establishment of sugar beets are inadequate and costly. Chemical control methods have been developed and adopted on a limited scale in the irrigated regions east of the Rocky Mountains. The problems in developing improved and economical weed control measures are different in rain-grown and irrigation-grown sugar beets. The need for weed control measures has been intensified by the introduction of monogerm sugar beet seed. Since monogerm sugar beets generally are not hand-thinned it is imperative that chemical weed control methods be developed; otherwise the use of monogerm seed and mechanization of production will not move forward. Efficient and economical chemical methods and combination chemical and cultural measures for controlling weeds in both rain-grown and irrigation-grown sugar beets are urgently needed.

5. Tobacco

Weeds in seedbeds are a particular problem in tobacco production. Dodder, morning-glory, clover, and certain other weeds are not controlled by the most effective fumigant in use. Much labor and expense are necessary to handhoe or pull weeds around tobacco plants in the field. Cultivation for weed control frequently injures tobacco roots. Research is needed to develop safe and economical chemical and combination chemical-cultural methods of weed control in tobacco plant beds and in tobacco fields following planting.

<u>Lines of research that apply to weed control in agronomic crops are as follows:</u>

Develop improved pre-planting, pre-emergence, post-emergence, and lay-by chemical weed control techniques.

Design and improve herbicide-application equipment and develop and devise mechanical techniques for extending the selectivity of chemical methods of control.

Determine the effects of herbicides on the germination and quality of treated agronomic crop plants.

Develop chemical and combination chemical-cultural methods of controlling weeds, including determination of the relative cost of different methods alone and in combination and the benefits of control measures.

Develop methods of utilizing chemicals to control weeds selectively in crops so as to leave little or no residue in the crop and soil.

Investigate the rotational use of herbicides and mixtures of herbicides alone and in combination with cultural, crop-competition, crop-rotation, and biological methods of weed control to determine the efficiency of these methods in depleting cropland of weed populations without the accumulation of harmful herbicide residues.

Determine the effects of natural environmental factors, the method of treatment, rate of application, and time of application on the efficiency of herbicidal treatments.

Study the ecological responses of crops and associated weeds to herbicides.

Study the effects of time of appearance, duration, and intensity of weed competition and develop evaluation criteria for measuring these competitive effects and the benefits from control of weeds.

Study the different varietal responses of crop plants to herbicides.

Study the effects of herbicides on subsequent crops grown in rotation.

B. In horticultural crops

The control of weeds has become a critically limiting economic problem in the production of many horticultural crops. Present methods of mechanical and chemical control are inadequate, and new and improved methods must be devised if this economic challenge is to be met effectively.

1. Vegetable crops

Major weed problems in vegetable crops occur in the plant-bed, in the field at emergence, and after the last cultivation. In such vegetables as broccoli, Brussels sprouts, cabbage, cantaloupes, cauliflower, eggplant, peppers, and tomatoes some of the principal plant-bed weeds are crabgrass, lambsquarters, and pigweed. Research is needed to develop low-cost effective soil fumigants, equipment, and techniques to treat plant-bed soils. Direct-seeded vegetables such as beans, collards, kale, peas, spinach, turnips, sweet corn, and many others must compete at emergence with such weeds as chickweed, crabgrass, goosegrass, henbit, knotweed, lambsquarters, pigweed, purple lovegrass, ragweed, smartweed, and many other annual weeds before cultivation is possible. Effective pre-planting or pre-emergence herbicides, equipment, and techniques are needed to solve these urgent problems in direct-seeded vegetables. Annual weeds such as barnyard-grass, crabgrass, fall panicum, goosegrass, lambsquarters, pigweed, ragweed, and smartweed which emerge after the last cultivation of beans, cantaloupes, cucumbers, peppers, squash, sweet potatoes, tomatoes, white potatoes, and many other vegetables, reduce yields and quality and promote disease and insect damage. Hand labor for weeding is becoming increasingly scarce and costly and the need for effective herbicides and application techniques for use after the last clean cultivation is crucial in the continuance of commercial production of many vegetables.

In many areas where vegetables are grown commercially, perennial weeds including Bermudagrass, Johnsongrass, and nutsedge constitute severe problems, and intensive research on a broad front is needed to develop economical methods of control for these weeds in all vegetable crops.

2. Fruit and nut crops

Weeds that compete with fruit and nut crops, including small fruits, orchard fruits, and tree nuts are annual and perennial herbaceous weeds and woody brush weeds such as brambles, greenbrier, honeysuckle, poison ivy, and numerous volunteer tree seedlings. Mechanical cultivation is inefficient and severely damages the root systems when employed too vigorously. The cost of hand weeding strawberries frequently exceeds $200 per acre. New and improved chemical methods alone and in combination with improved mechanical methods can reduce production costs, improve yield, quality, and longevity of many of these crops. Research to develop these methods is needed.

3. Ornamental crops

Weeds constitute critical economic problems in nursery and field plantings of the multitude of ornamental crops including bulb crops, perennial and annual herbaceous crops, and perennial woody crops. Annual weeds such as barnyardgrass, chickweed, crabgrass, carpetweed, fall panicum, goosegrass, henbit, lambsquarters, pigweed, purslane, ragweed, and others compete with these crops. Serious perennial weeds include Bermudagrass, Johnsongrass, nutsedge, and wild chrysanthemum. The control of these perennial weeds in the soil around balled and potted nursery plants is vital in preventing their dissemination. The growth and quality of ornamentals are greatly impaired by competition with weeds, and new and improved methods of control can provide extensive economic benefits to the industry. Research should be initiated to develop effective soil-fumigant and field pre-planting, pre-emergence, and post-emergence herbicide treatments.

<u>Lines of research that apply to weed control in horticultural crops are as follows:</u>

Develop pre-planting, pre-emergence, and post-emergence techniques for controlling weeds in horticultural crops.

Develop effective, safe, and practical methods of utilizing herbicides under different environmental and cultural conditions.

Develop methods of utilizing herbicides so as not to impair the composition and quality of food crops or to leave harmful residues at harvest.

Determine the effect of rainfall and other natural environmental factors on the performance, selectivity, and persistence of herbicides.

Develop specific methods of herbicide application for the various horticultural crops growing in different kinds of soils.

Determine the effects of land preparation, planting, cultivation, and crop varieties on herbicide performance and practical usefulness.

Determine the effect of the amount and time of irrigation on the performance of herbicides.

Determine the effect of time, rate and method of application, and formulation on the effectiveness of herbicides.

Determine the residual effect of herbicides on succeeding crops.

C. In forage, pastures, and rangelands

Weed control in pastures and ranges is characterized by special problems. Forages frequently are composed of a number of plant species, often several grasses. In the humid regions, however, desirable species of legumes also are included and in rangelands desirable browse species, such as winterfat and bitter brush, are interspersed with undesirable brush. Herbicides with a spectrum broad enough to kill many types of weeds frequently eliminate certain desirable species as well. A high degree of specificity is required both in chemical and biological agents.

1. Native and established permanent pastures of the humid regions

Of the 230 million acres of grazing land in the 31 Eastern States, which provide the pasturage for 54% of the country's livestock, 80% is in permanent pastures and rangelands. Many of these permanent pastures are infested with weeds and brush and produce far below their potential. The production of these pastures could be improved vastly through development of efficient and

economical renovation practices, which include control of brush and weed species and improvement of the plant population through the development of management practices that will expedite replacement of low-quality plants with desirable forage species.

2. Rangelands

The rangelands of the West are seriously infested with low-value woody and herbaceous species. In the high altitudes of the Southwest juniper has spread over 75 million acres of rangelands. Over 100 millinn acres of the intermountain region are covered with sagebrush. Poisonous plants are serious problems in some areas. Large areas of the southern Great Plains and the Southwest are infested with mesquite and of the central and southern intermountain region with oak brush. Significant portions of brush-infested lands have good forage-production potentials.

Effective methods of killing certain brush species such as big and sand sagebrush with herbicides have been devised. Present chemicals are much less effective on certain species, such as mesquite, and more effective methods must be developed. Resprouting species, such as many of the oaks and alligator juniper, with present herbicides require repeated follow-up treatments for their control. The use of insects and other biological control agents to reduce infestation has not been investigated adequately, but the phenomenal control of Klamath weed with insects points the way to success by this method.

Elimination of undesirable species is the first step in upgrading range vegetation. Subsequent competition from desirable vegetation is needed to minimize reinvasion. Plant replacement, in fact, is another form of biological control.

In areas where an understory of grasses has persisted, proper management systems permit reinvasion of desirable forage species after brush and weed removal. In other large areas no residue of grass remains, and removal of the brush results in serious erosion by both wind and water. Brush control must be followed with replacement vegetation both for increasing productivity and for reducing reinvasion by undesirable species. In many areas revegetation is exceedingly difficult and basic research is necessary for the development of effective establishment methods. Economical systems involving control of brush and weeds, replacement of vegetation, and management to maintain favorable vegetation are seriously needed.

3. Forage grown for hay

The quality and yield of hay on many hayfields are reduced by the invasion of weed species such as Canada thistle, curly dock, milkweed, wild carrot, ragweed, and nutsedge. Safe and economical methods of selective control by herbicides, together with development of management systems, to prevent weed invasion in grass and legume meadows are needed.

4. New seedings of forage crops

Competition by weeds causes frequent failures in establishing forage crops and is among the most serious deterrents to successful seedling establishment. Pastures in the South, propagated vegetatively, also could be established with less losses if management systems that would reduce weed competition were developed. Establishment practices which through the effective control of weeds would reduce the frequency of failures of establishing stands and thereby lower production costs are needed.

Lines of research that apply to weed control in forages, pastures, and rangelands are as follows:

Develop improved pre-planting, pre-emergence, and post-emergence chemical weed control techniques.

Develop chemical, cultural and combination methods for controlling weeds, poisonous plants, and brush, including determination of the costs of different methods alone and in combination, in relation to the forage production potential in various soil climate areas.

Develop methods of utilizing chemicals to control selectively broadleaved and grassy weeds and brush in mixed stands of forages (legumes and grasses) so as to leave no harmful residues on the plants desired or in the soil.

Determine the effects of natural environmental factors, and the method, rate, and time of application on the efficiency and selectivity of herbicidal treatments.

Study the effects of weed control methods and management systems, alone and in combination, on the ecological changes of vegetation including forage and browse species and associated weeds in pastures and rangelands.

Appraise selective herbicides for efficiency as follow-up treatment to control resprouting of brush plants.

Appraise various insects and disease-causing and other organisms for effectiveness in biological control of weeds and brush plants.

Appraise the value of joint grazing by sheep or goats with cattle for suppressing weed growth in pastures.

Develop management systems to enhance reinvasion, or establishment from seeding, of desirable forage species to replace brush and weeds removed by chemical, cultural or other treatments.

Develop special equipment for more efficient eradication or control of brush in rangelands.

D. In crops grown for seed production

Weed control problems in crops grown specifically for seed production require special attention. In the production of seed outside of the principal region of use, as is done for small-seeded forage legumes and forage and turf grasses, methods of growing the crop for seed are frequently different from those of growing it for commercial use. Establishment of new seedings, particularly with respect to elimination of competition from weeds, presents a special problem.

Seed purity is of primary importance. When legume seeds become contaminated with seeds of weeds such as dodder, black medic, and wild mustard or when seeds of turf and forage grasses are infested with seeds of grassy weeds such as quackgrass and weedy bromegrass, mechanical elimination of all weed seeds is virtually impossible. As a consequence market quality is lowered seriously. In fact contamination with certain noxious weeds prohibits sale of the product.

Loss of genetic purity through volunteer plants which occur following the first seed harvest or result from sprouting of hard seeds remaining in the soil from previously grown crops is of serious concern to seed growers. Incorporation of chemical and other control measures into management systems to prevent the growth of volunteer seedlings will greatly reduce seed production costs through permitting a greater number of seed harvests from perennial species and reusage of the land for the same crop at more frequent intervals.

Lines of research needed to meet weed control problems in crops grown for seed production are as follows:

Develop methods for control of weeds in crops grown for seed, especially those weeds producing seed that cause serious contamination of the crop seed.

Study the interaction of cultural and chemical weed control practices on the set, development, yield, purity and quality of grass and legume seed.

Develop methods for control of volunteer plants resulting from seed that shattered from a previous seed harvest involving differential response of seedlings and mature plants to chemical or other methods.

Study the effects of application of herbicides on the vitality and genetic stability of harvested grass and legume seeds.

Study the effects of herbicides on yield and vitality of stolons, rhizomes or other plant parts essential to the perpetuation of varieties and species propagated by asexual means.

E. For timber stand and forest range improvement

Forest lands largely are relatively undisturbed areas in which a stable vegetation type is characteristically predominant. Through harvest of desirable species of timber and forage plants, man often upsets the ecological balance. Plant successions of undesirable vegetation frequently greatly lower the economic usefulness of forest lands. Control measures are needed to eliminate or retard undesirable vegetation and restore maximum productivity. Many of these lands are part of the public domain. In the development of measures to control undesirable vegetation other uses for these lands, such as for recreation areas and as wildlife preserves, also must be considered.

1. Timber stand improvement

Many stands of softwood timber are being overgrown with less desirable hardwood species. A good share of the 14 million acres of conifer plantations presently are in need of release from competing and overtopping vegetation. Most of the 50 million acres that currently need planting are covered with dense brush or other competing vegetation that require removal with chemicals, machines, or fire or combination methods prior to successful regeneration. A considerable portion of the 10 to 12 million acres of timber that are cut over annually are subject to invasion by heavy growths of shrubby vegetation that require control.

Methods of control through the use of herbicides and fire that will kill hardwood species overgrowing young softwood timber stands and will selectively eliminate low-quality trees and brush from hardwood stands are required.

2. Forest rangeland improvement

The grazing value of most forest rangeland for both domestic and game animals has been substantially reduced by invasion with brush. In some areas poisonous weeds like larkspur and halogeton or mechanically injurious plants like Canada thistle or medusa-head wildrye are rendering large forest range areas useless or more costly to operate. The merits of using fire and chemicals in forest and rangeland management are controversial because they can be beneficial in some cases and detrimental in others. Further research is required to establish the values and limitations of fire as a practical and economical tool for improving grazing and vegetative habitat on brushy or low-quality ranges in the West and South. Management of livestock rangelands and wildlife habitats following control programs to reduce reinvasion also is in need of additional research.

F. For irrigation, drainage and other waters

The 1954 census of agriculture indicates almost 30 million irrigated acres. Other data indicate about 155,000 miles of irrigation canals and ditches. There is an approximately equal mileage of drainage ditches serving over 100 million acres of drained land. Artificial farm ponds and reservoirs numbered about 1-3/4 million in 1954.

Aquatic and bank weeds cause great losses to American agriculture each year. Floating weeds such as the water hyacinth reduce the flow of water in canals as much as 40 percent, whereas submerged weeds such as pondweeds may reduce it much more. Reduced flow causes flooding, seepage, poor drainage, and inadequate water for irrigating fields.

Some success has been achieved in controlling submersed aquatic weeds in small irrigation canals but the treatments are not suitable for large irrigation and drainage canals and the herbicides are toxic to fish and their use therefore is limited. Many aquatic weeds such as alligator weed cannot be controlled with current herbicides.

Lines of research that apply to weed control in irrigation drainage and other waters are as follows:

Develop economical and safe methods and equipment for controlling submersed and other aquatic weeds in large irrigation and drainage canals.

Develop effective, economical and safe chemical methods and equipment for controlling aquatic weeds in farm ponds and other static bodies of water that are used for irrigation, livestock water, fish production, recreation and domestic purposes.

Determine the effects of aquatic herbicides in irrigation water on selected crop plants under different environments.

Determine the effects of natural environmental factors, methods of treatment, and rates and times of application on the efficiency of herbicides.

Determine the relation of herbicide formulation and solubility on the rate and time of application and frequency of retreatment required for adequate control of aquatic weeds.

Determine effectiveness of competitive vegetatinn, insects and other biological agents for controlling aquatic weeds.

Determine the stage-of-development response of submersed, floating and emergent aquatic weeds to promising herbicides.

Determine the effect of water, plant, and soil characteristics on the disappearance of herbicides from water.

G. For weed-infested areas adjacent to crop lands

Weed growth in fence rows and in rights-of-way for highways and railroads is a serious problem. The many thousands of miles of township, county, state, and federal highways constitute narrow bands of land through agricultural areas, where seeds from uncontrolled weeds provide an extremely troublesome source of infestations on adjoining farmlands.

Research is required to develop effective, dependable, and safe soil-sterilant herbicides and application techniques for complete vegetation control in locations such as fence rows, ditchbanks, highway guard rails, bridge abutments, and utility-line poles. Research is needed also to determine the special chemical selectivities and the precise application techniques required for applying selective and non-selective herbicides in locations such as roadsides and railroad and utility-line rights-of-way.

H. In lawns and turf

Established turf in the United States, exclusive of that grown for sale as planting stock, is estimated to total 14 million acres with an estimated annual maintenance cost of $2 billion. Weedy grasses, such as crabgrass, quackgrass, and nutsedge, and broadleaved weeds, such as red sorrel, are particular problems.

Weed control research on lawns and turfs should include development of more effective herbicidal treatments and studies of competition between the weeds and desired grasses, the immediate and long-time effects of repeated applications of herbicides on the germination and growth of grasses, and the interactions of herbicidal applications, clipping practices, and soil fertility. Particular attention should be devoted to the development of superior management practices including the use of herbicides to assist in reducing maintenance costs.

STAFFING REQUIREMENTS

In the determination of additional staff needed to carry on a minimal adequate research program on weed control, attention was focused on problems of national and regional significance appropriate for Department attention. Each line of research, enumerated in detail in the preceding section, Research Needs, was examined as to adequacy of present level of research and, when the level was found inadequate, additional scientists required, by discipline, were determined. The additional federal staffing needs by lines of research are shown in Table 2 (pages 49-56) and summarized in Table 3 (page 57).

Table 2.

ADDITIONAL DEPARTMENT STAFFING NEEDS BY LINES OF RESEARCH

Lines of Research	Staffing Needs[1/]
I BASIC WEED CONTROL RESEARCH THAT APPLIES TO MOST CROPS AND SITUATIONS	
A. Evaluation of chemicals and insects and other biological agents for weed control	1 Biochemist 1 Chemist 3 Plant Physiologists 1 Plant Pathologist 3 Entomologists (9 Scientists)
1. Development of evaluation techniques and equipment	
2. Determination of activity and selectivity of agents	
3. Search for new and more effective agents	
B. Determination of the nature, behavior, and effects of herbicides and their degradation products	
1. In and on plants and plant products	7 Biochemists[2/] 2 Chemists[2/] 14½ Plant Physiologists[2/] ½ Nutritionist
a. Absorption, penetration, and translocation	
b. Mechanisms by which herbicides affect plants	
(1) Varietal and biotype influences	
(2) Chemical, physical, physiological, and morphological factors	
c. Metabolism and degradation products	
d. Influence of environmental factors	
e. Form and amount of herbicide residues	
f. Effects on chemical composition and quality of the crop	

1/ Designated on the basis of professional scientists each provided with one agricultural research technician, secretarial assistance and operating funds.

2/ Includes 3 Biochemists, 2 Plant Physiologists, and 2 Chemists to study herbicide metabolism in plants at Metabolism Laboratory, Fargo, North Dakota

Lines of Research	Staffing Needs[1/]
2. In and on soils in relation to weed control and crop production	
a. Movement and persistence of herbicides	1 Horticulturist 2 Plant Physiologists
b. Interactions of herbicides with soil (1) Physical (2) Chemical (3) Microbiological	1 Soil Physicist 2 Chemists (Soil) 1 Microbiologist
c. Ultimate fate of herbicides	1 Plant Physiologist
d. Form and amount of herbicide residues	1 Plant Physiologist
3. In irrigation, drainage and other waters a. Irrigation, distribution, and drainage systems b. Lakes, ponds, and reservoirs c. Meadows, marshes, and swamps d. Streams, rivers and estuarine waters	1 Biochemist ½ Biologist (Aquatic) 1 Engineer (Hydraulic)
4. In and on animals and animal products a. Metabolism and degradation in animals b. Acute and chronic effects on domestic and wild animals c. Residues in and effects on animal products (1) Milk (2) Meat (3) Eggs (4) Fish and game	1 Chemist[3/] 1 Biochemist[3/] 3 Veterinarians
	(40½ Scientists)

3/ To study herbicide metabolism in animals at Metabolism Laboratory, Fargo, North Dakota

Lines of Research	Staffing Needs[1/]
C. Development of principles of mechanics of herbicide application and weed seed removal	3 Agr. Engineers 1 Mathematician
1. Herbicide deposits on plants and in the soil including particle size and mass distribution	
2. Mechanics of forces affecting particle deposition; characteristics of special formulations such as granules; inert emulsions and volatile materials	
3. New principles, equipment, and techniques for separating weed seeds during both on-the-farm and commercial cleaning	
	(4 Scientists)
D. Determination of weed characteristics and weed control in relation to desired plants and the feasibility of control practices under different conditions	
1. Life cycles and growth habits of weeds under different environments, including their susceptibility to control agents at different stages and the germination and longevity of weed seeds	3½ Ecologists 1 Horticulturist 1 Agronomist
2. Relations between weeds and the biological control organisms that attack them under different environments	1 Botanist 1 Entomologist
3. Competition between weeds and desired plants and plant successions following control measures including replacement vegetation and management measures	5 Agronomists 1 Plant Physiologist
4. Evaluation of genetic potential for increasing tolerance of crop plants to herbicides	1 Geneticist
5. Spread of weeds through transportation and marketing channels a. Movement of domestic seed b. Importation of foreign seed	1 Botanist

Lines of Research	Staffing Needs[1/]
c. Movement of grains, hay and other feeds	
d. Movement of nursery stock	
6. Legal and regulatory activities	1 Economist
7. Effects of chemical weed control measures on the ecology and environment of fish and wildlife	1 Biologist (Aquatic) 1 Biologist (Wildlife)
8. Evaluation of weed damages, values and benefits of control	5 Economists ½ Nutritionist ½ Soil Scientist (24½ Scientists)
Subtotal Item I	(78 Scientists)

II RESEARCH THAT APPLIES TO WEED CONTROL IN SPECIFIC CROPS OR SITUATIONS

Development of safe and economical methods and equipment for weed control, including chemical, cultural (including burning), and biological methods, and integration of control measures into efficient management systems

A. In agronomic crops	
1. Cereal crops	
a. Corn	2 Agronomists ½ Agr. Engineer 1 Plant Physiologist
b. Sorghum	1 Agronomist

Lines of Research	Staffing Needs[1/]
c. Small grains (wheat, oats, barley, rice)	2½ Agronomists 1 Physicist (Soil) 1 Agr. Engineer
2. Cotton	2 Plant Physiologists[4/] 2 Agronomists 2 Agr. Engineers
3. Oilseed crops	
a. Soybeans	1½ Agronomist ½ Agr. Engineer
b. Peanuts	1 Agronomist
c. Others (safflower, castorbeans, sesame, flax)	1 Agronomist
4. Sugar crops	
a. Sugarcane and sweet sorghum	1 Agronomist
b. Sugar beets	1 Agronomist
5. Tobacco	1 Agronomist (22 Scientists)
B. In horticultural crops	
1. Vegetable crops a. Vegetable legume crops b. Vine crops c. Solanaceous crops d. Leaf, salad, and cole crops e. Root and bulb crops f. Other	5 Horticulturists 2 Agr. Engineers ½ Soil Scientist

4/ Currently supported by grant funds from Cotton Foundation for Research and Education

Lines of Research	Staffing Needs[1/]
2. Fruit and nut crops	3 Horticulturists 1 Agr. Engineer
a. Small fruit crops b. Orchard fruit crops c. Orchard nut crops	
3. Ornamental crops	1½ Horticulturist
a. Bulb crops b. Perennial herbaceous crops c. Perennial woody crops d. Herbaceous annuals e. Other	
	(13 Scientists)
C. In forage, pasture and rangelands	
1. Native and established permanent pastures of the humid regions	4 Agronomists 1 Soil Scientist
2. Rangelands	2 Plant Physiologists 6 Agronomists 3 Entomologists 1 Agr. Engineer
3. Forage grown for hay	1½ Agronomist
4. New seedings of forage crops	1½ Agronomist
	(20 Scientists)
D. In crops grown for seed production	1 Horticulturist 2 Agronomists
1. Agronomic crops	

Lines of Research	Staffing Needs[1/]
a. Forage legumes	
b. Forage grasses	
c. Turf grasses	
2. Horticultural crops	
a. Vegetables	
b. Ornamentals	
	(3 Scientists)
E. For timber stand and forest range improvement	
1. Timber stand improvement	1 Silviculturist
	1 Engineer
2. Forest rangeland improvement	1 Ecologist
	2 Range Conservationists
	(5 Scientists)
F. For irrigation, drainage and other waters	2½ Plant Physiologists
	1 Agr. Engineer
	1 Entomologist
	1 Ecologist
	(5½ Scientists)
G. For weed infested areas adjacent to croplands	1 Agronomist
1. Weed control along fence rows, ditchbanks, and other non-tilled areas	
2. Weed control in public and private utility rights-of-way and industrial sites	
	(1 Scientist)

Lines of Research	Staffing Needs[1/]
H. In lawns and turf	2½ Agronomists (2½ Scientists)
Subtotal Item II	(72 Scientists)
Total	150 Scientists

Table 3. SUMMARY OF ADDITIONAL DEPARTMENT STAFFING NEEDS BY LINES OF RESEARCH

Lines of Research	Number of Professional Positions[1/]	
I BASIC WEED CONTROL RESEARCH THAT APPLIES TO MOST CROPS AND SITUATIONS		78
A. Evaluation of chemicals and insects and other biological agents for weed control	9	
B. Determination of the nature, behavior and effects of herbicides and their degradation products	40½	
C. Development of principles of mechanics of herbicide application and weed seed removal	4	
D. Determination of weed characteristics and weed control in relation to desired plants and the feasibility of control practices under different conditions	24½	
II RESEARCH THAT APPLIES TO WEED CONTROL IN SPECIFIC CROPS OR SITUATIONS		72
A. In agronomic crops	22	
B. In horticultural crops	13	
C. In forage, pasture, and rangelands	20	
D. In crops grown for seed production	3	
E. For timber stand and forest range improvement	5	
F. For irrigation, drainage and other waters	5½	
G. For weed infested areas adjacent to crop lands	1	
H. In lawns and turf	2½	
Total		150

1/ Designated on the basis of professional scientists each provided with one agricultural research technician, secretarial assistance and operating funds.

FOR INTERNAL USE IN U.S. DEPARTMENT OF AGRICULTURE ONLY

ADDITIONAL DEPARTMENT STAFFING NEEDS BY LINES OF RESEARCH, BY SUB-REGIONS, BY AGENCIES, AND BY DIVISIONS.

12-14-60

	NORTHEAST		NORTH CENTRAL			SOUTHERN				INTER-MOUNTAIN		PACIFIC COASTAL														
	CENTRAL FARM	NO. ATLANTIC	CENTRAL	LAKE STATES	NO. GT. PLAINS	CENTRAL	COASTAL PLAINS	SOUTH ATLANTIC	SO. GT. PLAINS	CENTRAL	SOUTHERN	CENTRAL	SOUTH COASTAL	CR-CPRB	SWC	AH	FE	CR-FRRB	CR-CCRB	FS-TM	FS-RMWH	ADP	AE	ENT		
I BASIC WEED CONTROL RESEARCH - ALL CROPS AND SITUATIONS																										
A. EVALUATION OF CHEMICALS AND INSECTS AND OTHER BIOLOGICAL AGENTS	3 CPRB					1 ENT			1 CPRB	2 CPRB 2 ENT				6										3		9
B. NATURE, BEHAVIOR AND EFFECTS OF HERBICIDES AND DEGRADATION PRODUCTS																										
1. IN AND ON PLANTS AND PLANT PRODUCTS	2½ CPRB ½ AH	1 FS-TM	3 CPRB		7 CPRB (FARGO)	3 CPRB		1 FS-TM		1 CPRB		3 CPRB 2 FS-TM		19½		½				4					24	4[illegible]½
2. IN AND ON SOILS IN RELATION TO WEED CONTROL AND CROP PRODUCTION	2 CPRB 4 SWC		1 CPRB			1 CPRB							1 CPRB	5	4										9	
3. IN IRRIGATION, DRAINAGE AND OTHER WATERS						½ CPRB						1 CPRB 1 SWC		1½	1										2½	
4. IN AND ON ANIMALS AND ANIMAL PRODUCTS					2 AH (FARGO)				3 ADP							2						3			5	
C. PRINCIPLES OF MECHANICS OF HERBICIDE APPLICATION AND WEED SEED REMOVAL			3 AE									1 AE											4			4
D. WEED CHARACTERISTICS AND CONTROL UNDER DIFFERENT SITUATIONS																										
1. LIFE CYCLES AND GROWTH HABITS OF WEEDS UNDER DIFF. ENVIRONMENTS			2½ CPRB			½ CPRB						½ CPRB 1 FS-TM		4½						1					5½	24½
2. RELATIONS BETWEEN WEEDS AND THE BIOLOGICAL ORGANISMS THAT ATTACK										1 CPRB 1 ENT				1										1	2	
3. COMPETITION BETWEEN WEEDS AND DESIRED PLANTS AND PLANT SUCCESSIONS			1 CPRB				½ CPRB	1 CR-FR		1 CR-FR 1 FS-RM		½ CPRB	1 CR-FR	2				3			1				6	
4. EVALUATION OF GENETIC POTENTIAL FOR INCREASING PLANT TOLERANCE			1 CR-CC							–									1						1	
5. SPREAD OF WEEDS THROUGH TRANSPORTATION AND MARKETING CHANNELS	1 CPRB													1											1	
6. LEGAL AND REGULATORY ACTIVITIES	1 FE																1								1	
7. EFFECTS OF CHEMICAL WEED CONTROL ON FISH AND WILDLIFE			½ CPRB			½ CPRB							1 FS-RM	1							1				2	
8. EVALUATION OF WEED DAMAGES, VALUES AND BENEFITS OF CONTROL	½ AH		1 FE		1 FE	1 FE				1 FE		1 FE ½ SWC			½	½	5								6	
II WEED CONTROL RESEARCH THAT APPLIES TO SPECIFIC CROPS OR SITUATIONS DEVISING AND DEVELOPING SAFE AND ECONOMICAL METHODS																										
A. IN AGRONOMIC CROPS 1. CEREAL CROPS a. CORN		½ CPRB	2 CPRB ½ AE			½ CPRB								3									½		3½	[illegible]
b. SORGHUM									1 CPRB					1											1	
c. SMALL GRAINS		½ CPRB	1 CPRB		1 CPRB 1 AE 1 SWC									2½	1								1		4½	
2. COTTON						1 CPRB 1 AE	1 CPRB		1 CPRB 1 AE				1 CPRB	4									2		6	
3. OILSEED CROPS a. SOYBEANS			1 CPRB ½ AE			½ CPRB								1½									½		2	
b. PEANUTS							[illegible]							1											1	
c. OTHERS										1 CPRB				1											1	
4. SUGAR CROPS a. SUGAR CANE						[illegible]								1											1	
b. SUGAR BEETS										1 CPRB				1											1	
5. TOBACCO								1 CPRB						1											1	
B. IN HORTICULTURAL CROPS																										
1. VEGETABLE CROPS		½ CPRB		1 CPRB ½ AE		½ CPRB			1 CPRB			1 CPRB ½ AE ½ SWC	1 CPRB 1 AE	5	½								2		7½	13
2. FRUIT AND NUT CROPS		½ CPRB		1 CPRB ½ AE		½ CPRB						1 CPRB ½ AE		3									1		4	
3. ORNAMENTAL CROPS	1 CPRB						½ CPRB							1½											1½	
C. IN FORAGE, PASTURE AND RANGE LANDS																										
1. NATIVE AND ESTABLISHED PERMANENT PASTURES		1 CR-FR						2 CPRB 1 CR-FR 1 SWC						2	1			2							5	20
2. RANGE LANDS										2 CPRB 2 CR-FR 1 AE 2 ENT	2 CPRB (TEMPE)		1 CPRB 1 CR-FR 1 ENT	5				3					1	3	12	
3. FORAGE GROWN FOR HAY		1 CPRB				½ CR-FR								1				½							1½	
4. NEW SEEDINGS OF FORAGE CROPS						1 CPRB ½ CR-FR								1				½							1½	
D. CROPS GROWN FOR SEED PRODUCTION												1 CPRB 1 CR-FR	1 CPRB	2				1								3
E. FOR TIMBER STAND AND FOREST RANGE IMPROVEMENT																										
1. TIMBER STAND IMPROVEMENT		2 FS-TM																		2					2	5
2. FOREST RANGELAND IMPROVEMENT										2 FS-RM			1 FS-RM								3				3	
F. FOR IRRIGATION, DRAINAGE AND OTHER WATERS	1 CPRB					1 CPRB 1 AE 1 ENT							2 CPRB	3½									1	1		5½
G. FOR WEED-INFESTED AREAS ADJACENT TO CROPLAND								1 CPRB						1												1
H. IN LAWNS AND TURF	1 CPRB 1 CR-FR					½ CPRB								1½				1								2½
CR-CPRB	11	3	12	2	8	13	3	4	4	8	2	8	7	85												
SWC	4				1			1				2			8											
AH	1				2											3										
FE	1		1		1	1				1		1					6									
CR-FRRB	1	1				1		2		3		1	2					11								
CR-CCRB			1																1							
FS-TM		3						1				3								7						
FS-RMWH										3			2								5					
ADP									3													3				
AE			4	1	1	2			1	1		2	1										13			
ENT						2				5			1											8		
	18	7	18	3	13	19	3	8	8	21	2	17	13													150
	25		34			38				23		30														
[illegible]	10		1			5				2		3		24		2					1					27

* - Forest Service - Physiologist - moved to Beltsville
** - Forest Service Silviculturist - moved to Beltsville
Engineer stay at North Atlantic facility

Each line of research was examined as to the possibility of conducting it centrally at a single location. For certain basic phases, this is entirely feasible. When differences in regional application of the principles involved precluded conducting it at one location, the research was considered in light of the principal problem areas in weed control in the major regions of the United States. A minimum number of scientists were subsequently designated for conducting research on each specific line in a minimum number of regions.

For weed control research, continental United States was divided into five major regions: namely, Northeastern, North Central, Southern, Intermountain, and Pacific Coastal. Within each of these regions the need for a group of scientists from a number of disciplines to conduct research at a central location was found necessary. Such central location would permit maximum utilization of the team approach in solving problems of basic and applied nature. It was envisaged that this nucleus of scientists, located in each of the major regions, would also serve as a clearing house for information on weed control research conducted by scientists in state and federal agencies as well as by industry. Duplication of research effort could thereby largely be eliminated.

Not all important problems, however, can be solved at a central location within a major region. In some cases the principles developed in basic research must be tested under various environmental conditions in different subregions. In other instances the basic research itself can best be conducted where the pertinent weed occurs or the crop in question is grown. Major regions were consequently subdivided into major weed control problem areas designated as subregions. The subregions are as follows:

Region	Subregion
Northeastern	Middle Atlantic North Atlantic New England
North Central	Corn Belt Lake States Northern Great Plains
Southern	Delta States Coastal Plains Southern Appalachian Southern Great Plains
Intermountain	Central Intermountain Southern Intermountain Northern Intermountain
Pacific Coastal	Northwest Southern Coastal

Delineation of the subregions is shown on a map (Fig. 1, page 60).

The regional pattern of additional Department staffing requirements by agencies is shown in Table 4 (page 61). The number of professional positions required in each of the subregions or problem areas is indicated. In subregions omitted it was felt that the Department's responsibility in research could be cared for effectively at the central regional location or in one of the other subregions.

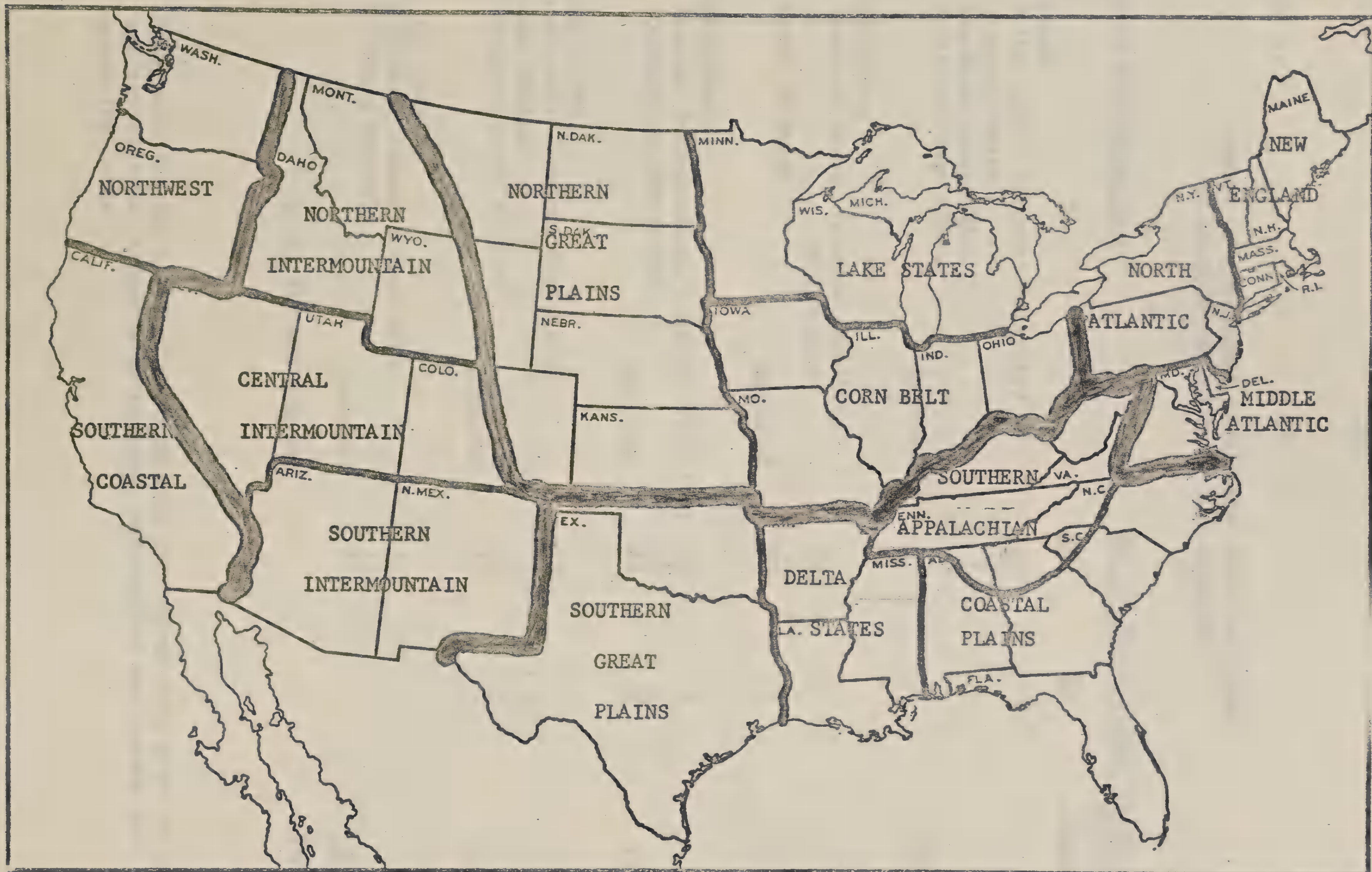

Fig. 1. Delineation of major weed control problem areas--designated as subregions.

Table 4.

SUMMARY OF ADDITIONAL DEPARTMENT STAFFING NEEDS
BY REGIONS, SUBREGIONS, AND AGENCIES

Regions and Subregions	No. of Professional Positions[1/]		
	ARS	FS	Regional Totals
Southern			
Delta States (central facility)	19	-	
Coastal Plains	3	-	
Southern Appalachian	7	1	
Southern Great Plains	8	-	
Subtotal	37	1	38
Northeastern			
Middle Atlantic (central facility - Beltsville)	18	-	
North Atlantic	4	3	
Subtotal	22	3	25
Intermountain			
Central Intermountain (central facility)	18	3	
Southern Intermountain	2	-	
Subtotal	20	3	23
North Central			
Corn Belt (central facility)	18	-	
Lake States	3	-	
Northern Great Plains	13	-	
Subtotal	34	-	34
Pacific Coastal			
Northwest (central facility)	14	3	
Southern Coastal	11	2	
Subtotal	25	5	30
Total for all regions			150

1/ Designated on the basis of professional scientists each provided with one agricultural research technician, secretarial assistance and operating funds.

FACILITY AND EQUIPMENT REQUIREMENTS

In the development of the staffing pattern, previously discussed, it was determined that effectiveness of weed control research would be enhanced by providing a nucleus of scientists from the various pertaining disciplines to work as a team in each of the five major regions. Current federal and state installations are inadequate to provide the facility needed for the group within each of the regions.

For each of the five central locations, the requirements for facilities and equipment have been developed and are shown on Tables 5 - 9. Facilities and equipment as listed provide accommodation for the suggested additional staff as well as for a limited number of federal scientists presently conducting research within the region. The latter scientists can be located at the central facility provided it is located in the designated problem area, preferably at the site of one of the land grant colleges.

The suggested location of the regional central facilities by weed problem areas is as follows:

Region	Location of Facility (subregion)
Southern	Delta States
Northeastern	Middle Atlantic (Beltsville)
Intermountain	Central Intermountain
North Central	Corn Belt
Pacific Coastal	Northwest

The delineation of the subregions as developed in this report are shown on a map (Fig. 1, page 60).

In the subregions other than those containing the central facilities it is anticipated that additional scientists will be located with staff members conducting current research and can be housed in state or federal laboratories presently available. Needed items of equipment can be provided with funds made available for staffing prior to initial dates of employment of the additional scientists.

Table 5.

FACILITIES AND EQUIPMENT REQUIRED AT CENTRAL FACILITY
SOUTHERN REGION
(DELTA STATES)

	Sq. Ft.* Gross
Main Building	
Laboratories	6,840
Office space	6,324
Specialized equipment rooms	480
Engineering research shop	1,000
Greenhouse-Headhouse	
Greenhouse	12,600
Headhouse	4,800
Controlled environment chambers	600
Shop and Storage	
Unheated storage	1,000
Heated maintenance shop	500

Major Equipment

1. Aquatic weed tanks, autoclaves, centrifuges, chromatographic apparatus, electrophoresis equipment, germinators, isotopic equipment, meteorological equipment,spectrophotometers, and temperature tanks.

2. Electronic particle size analyzer.
(Microscope and associated electronic equipment that will permit the scanning of pesticide deposits and rapid determination of the size distribution of spray droplets. Will permit design of most effective spray equipment. Similar research necessary for dust and granular chemicals.)

3. Equipment for engineering research shop.
Lathes, hydraulic presses, welders and other metal working tools.

* Includes 20% for halls, walls, etc., in main building

In addition to the facilities shown, provision is to be made for veterinary toxicological studies at Kerrville, Texas.

Table 6.

FACILITIES AND EQUIPMENT REQUIRED AT CENTRAL FACILITY
NORTHEASTERN REGION
(MIDDLE ATLANTIC - BELTSVILLE)

	Sq. Ft.* gross
Main Building	
Laboratories	9,180
Office space	7,224
Specialized equipment rooms	900
Engineering research shop	1,000
Greenhouse-Headhouse	
Greenhouse	13,600
Headhouse	4,800
Controlled environment chambers	800
Shop, Storage, Garage	
Unheated storage	1,500
Heated maintenance shop	500

Major Equipment

1. Autoclaves, centrifuges, chromatographic apparatus, electrophoresis equipment, germinators, isotopic equipment, meteorological equipment, spectrophotometers, and temperature tanks.

2. Equipment for engineering research shop. Lathes, hydraulic presses, welders and other metal working tools.

* Includes 20% for halls, walls, etc., in main building

Table 7.

FACILITIES AND EQUIPMENT REQUIRED AT CENTRAL FACILITY
INTERMOUNTAIN REGION
(CENTRAL INTERMOUNTAIN)

	Sq. Ft.* Gross
Main Building	
Laboratories	8,100
Office space	7,128
Specialized equipment rooms	360
Engineering research shop	1,000
Greenhouse-Headhouse	
Greenhouse	15,900
Headhouse	4,800
Controlled environment chambers	600
Shop, Storage, Garage, Incinerator	
Unheated storage	1,500
Heated maintenance shop	500

Major Equipment

1. Aquatic weed tanks, autoclaves, centrifuges, chromatographic apparatus, electrophoresis equipment, germinators, isotopic equipment, meteorological equipment, spectrophotometers, and temperature tanks.

2. Equipment for engineering research shop.
   Lathes, hydraulic presses, welders and other metal working tools.

* Includes 20% for halls, walls, etc., in main building

Table 8.

FACILITIES AND EQUIPMENT REQUIRED AT CENTRAL FACILITY
NORTH CENTRAL REGION
(CORN BELT)

	Sq. Ft.* Gross
Main Building	
Laboratories	3,960
Office space	5,604
Specialized equipment rooms	360
Engineering research shop	1,000
Greenhouse-Headhouse	
Greenhouse	9,100
Headhouse	4,800
Controlled environment chambers	600
Shop, Storage, Garage	
Unheated storage	1,200
Heated maintenance shop	500

Major Equipment

1. Autoclaves, centrifuges, chromatographic apparatus, Electrophoresis equipment, germinators, isotopic equipment, meteorological equipment, spectrophotometers, and temperature tanks.

2. Major equipment items needed for the Metabolism Laboratory, Fargo, North Dakota - same as item #1.

3. Equipment for engineering research shop. Lathes, hydraulic presses, welders and other metal working tools.

* Includes 20% for halls, walls, etc., in main building

Table 9.

FACILITIES AND EQUIPMENT REQUIRED AT CENTRAL FACILITY
PACIFIC COASTAL REGION
(NORTHWEST)

	Sq. Ft.* Gross
Main Building	
Laboratories	4,680
Office space	5,868
Specialized equipment rooms	360
Engineering research shop	1,000
Greenhouse-Headhouse	
Greenhouse	8,600
Headhouse	4,800
Controlled environment chambers	400
Shop, Storage, Garage	
Unheated storage	1,000
Heated maintenance shop	500

Major Equipment

1. Autoclaves, centrifuges, chromatographic apparatus, electrophoresis equipment, germinators, isotopic equipment, meteorological equipment, spectrophotometers, and temperature tanks.

2. Equipment for engineering research shop. Lathes, hydraulic presses, welders and other metal working tools.

* Includes 20% for halls, walls, etc., in main building

SUMMARY

Weeds and the difficulties of controlling them represent a significant drain on the agricultural economy of our country. Many methods have been tried in an effort to reduce the detrimental effects of weeds. Since World War II the development of promising, selective chemicals has created new potentials for reduction in labor and other production costs.

At present a significant amount of research is being directed toward solution of the weed problem. State and Federal scientists representing several disciplines are devoting major efforts toward the curtailment of weeds. Although the research is too widely scattered for most efficient progress, approximately 120 man-years by Federal scientists and 150 by State scientists are devoted annually to research related to weed control.

Expansion of research on all promising methods of reducing the weed burden on the agricultural economy is essential. This is especially true if best use is to be made of mechanical harvesting and processing improvements. It is necessary to expand our knowledge of: promising herbicides and the spectrum of weeds and crops to which they are effectively applicable; the most advantageous timing of the application for greatest weed-killing results and for elimination of harmful residues; the most efficient methods of applying the chemicals; the use of plant-attacking insects and diseases; and, how to incorporate control practices into efficient management systems which suppress weeds and encourage crop plants. In order to assess properly these various methods, research on their long-term effects and the relative value of the methods must accompany the research on immediate effects.

Analyses of the most important weed problems and the geographical areas in which expansion of research is necessary have been made. Minimum requirements for a balanced program have been estimated to necessitate 150 Department scientists over the present man-power. Because solutions of the many problems require proximity of scientists to the areas of the country where particular weeds are most serious, geographical distribution of the scientists into five regions has been proposed.

In each of these regions provisions should be made for a team of scientists representing various disciplines to develop principles of weed control. Additionally, scientists in other problem areas of the region are required to extend basic findings to the field.

Because present facilities are inadequate to house a team of scientists, and highly specialized equipment is needed, preliminary estimates for regional facilities have been developed. Present facilities for scientists who will extend basic findings to the field are more nearly adequate.

A study of the Department's research needs on the problem of saltcedars and other phreatophytes also has been made and a report has been submitted. The findings for research needs in the two studies are separate and do not duplicate each other.

APPENDIX

Contributors to the Study

Beltsville, Maryland, October 24, 1960

Entomology Research Division, ARS, USDA

R. G. Dahms
C. H. Hoffmann
J. K. Holloway
E. F. Knipling
R. I. Sailer
G. B. Vogt

Animal Husbandry Research Division, ARS, USDA

N. R. Ellis
Ivan L. Lindahl
L. A. Moore
E. J. Warwick

Animal Disease and Parasite Research Division, ARS, USDA

E. R. Goode, Jr.
H. W. Johnson
A. M. Lee

Washington, D. C., October 25, 1960

Bureau of Reclamation, U. S. Department of Interior

Robert Balcom
F. L. Timmons[1/]

Fish and Wildlife Service, U. S. Department of Interior

Winston E. Banks
James E. Beach
Ray C. Erickson
Bruno von Limbach

National Park Service, U. S. Department of Interior

S. T. Carlson
Robert B. Moore
A. E. Rabitt

Washington, D. C., October 26, 1960

Bureau of Indian Affairs, U. S. Department of Interior

Evan Flory
L. W. Rogers
James D. Simpson
Lonnie E. Surrett

Bureau of Land Management, U. S. Department of Interior

W. H. Berry
Claire Letson

Farm Economics Research Division, ARS, USDA

D. C. Myrich
M. L. Upchurch
James Vermeer

1/ Leader, Weed Investigations--Aquatic and Non-crop Areas, Crops Protection Research Branch, Crops Research Division, ARS, USDA

Washington, D. C., October 27, 1960

National Agricultural Chemicals Association

Jack Dreessen
Lea Hitchner

Federal Extension Service, USDA

J. M. Saunders

Department of Defense

H. L. Blakey, Corps of Engineers, U. S. Army
C. L. Hamilton, Bureau of Docks, U. S. Navy
B. F. Kiltz, Corps of Engineers, U. S. Army
Homer S. Thompson, Grounds Maintenance, U. S. Air Force
F. L. Timmons[1/]

Forest Service, USDA

T. F. McLintock
Carl E. Ostrom
K. W. Parker

Washington, D. C., October 28, 1960

Plant Pest Control Division, ARS, USDA

E. D. Burgess
L. F. Curl
Kenneth Messenger
D. R. Shepherd
Joseph F. Spears

Plant Quarantine Division, ARS, USDA

Willis H. Wheeler

Agricultural Conservation Program Service, USDA

Thomas L. Ayers
G. E. Bradley

Commodity Stabilization Service, USDA

H. H. Shepard

Beltsville, Maryland, October 28, 1960

Agricultural Marketing Service, USDA

C. Golumbic
O. L. Justice
S. F. Rollin

Washington, D. C., October 31, 1960

Soil Conservation Service, USDA

A. D. Stoesz
H. C. Fletcher[2/]

Rural Electrification Administration, USDA

Clifford J. Waldron

Beltsville, Maryland, October 31, 1960

Agricultural Engineering Research Division, ARS, USDA

William Bruce
L. A. Liljedahl
E. G. McKibben

Beltsville, Maryland, November 1, 1960

Soil and Water Conservation Research Division, ARS, USDA

F. E. Allison
Tom Army
L. A. Dean
Maurice Fried
C. R. Miller
M. A. Norland
D. D. Smith

Crops Research Division, Fruit and Nut Research Branch, ARS, USDA

L. C. Cochran
H. L. Crane
A. Leon Havis
D. H. Scott
L. L. Danielson[3/]

2/ ARS-SCS Liaison Officer
3/ Leader, Weed Investigations--Horticultural Crops, Crops Protection Research Branch, Crops Research Division, ARS, USDA

Crops Research Division, Vegetable and Ornamentals Research Branch
ARS, USDA

R. V. Akeley
V. R. Boswell
Elmo W. Davis
S. L. Emsweller
A. E. Kehr
W. J. Zaumeyer
L. L. Danielson[3]

Beltsville, Maryland, November 2, 1960

Crops Research Division, Forage and Range Research Branch, ARS, USDA

Hugo O. Graumann
A. A. Hanson
Mason A. Hein
Wesley Keller
Darell E. McCloud
D. L. Klingman[4]

Beltsville, Maryland, November 3, 1960

Crops Research Division, Cereal Crops Research Branch, ARS, USDA

L. P. Reitz
Lloyd Tatum
G. A. Wiebe
W. C. Shaw[5]

Crops Research Division, Cotton and Cordage Research Branch, ARS, USDA

C. F. Lewis
B. M. Waddle
W. C. Shaw[5]

Crops Research Division, Oilseed and Industrial Crops Research Branch
ARS, USDA

W. K. Bailey
J. O. Culbertson
H. W. Johnson
L. M. Pultz
W. C. Shaw[5]

Crops Research Division, Tobacco and Sugar Crops Research Branch
ARS, USDA

J. E. McMurtrey, Jr.
Dewey Stewart
I. E. Stokes
H. M. Tysdal
W. C. Shaw[5]

Washington, D. C., November 7, 1960

Territorial Experiment Stations Division, USDA

D. V. Lumsden

4/ Leader, Weed Investigations--Grazing Lands, Crops Protection Research Branch, Crops Research Division, ARS, USDA
5/ Leader, Weed Investigations--Agronomic Crops, Crops Protection Research Branch, Crops Research Division, ARS, USDA

The members of the Working Group, all in the Agricultural Research Service at Beltsville, Maryland, appointed to study the research needs for the weed control problem were as follows:

W. H. Anderson, Entomology Research Division
W. M. Carleton, Agricultural Engineering Research Division
W. B. Ennis, Jr. (secretary), Crops Research Division
M. G. Weiss (chairman), Crops Research Division